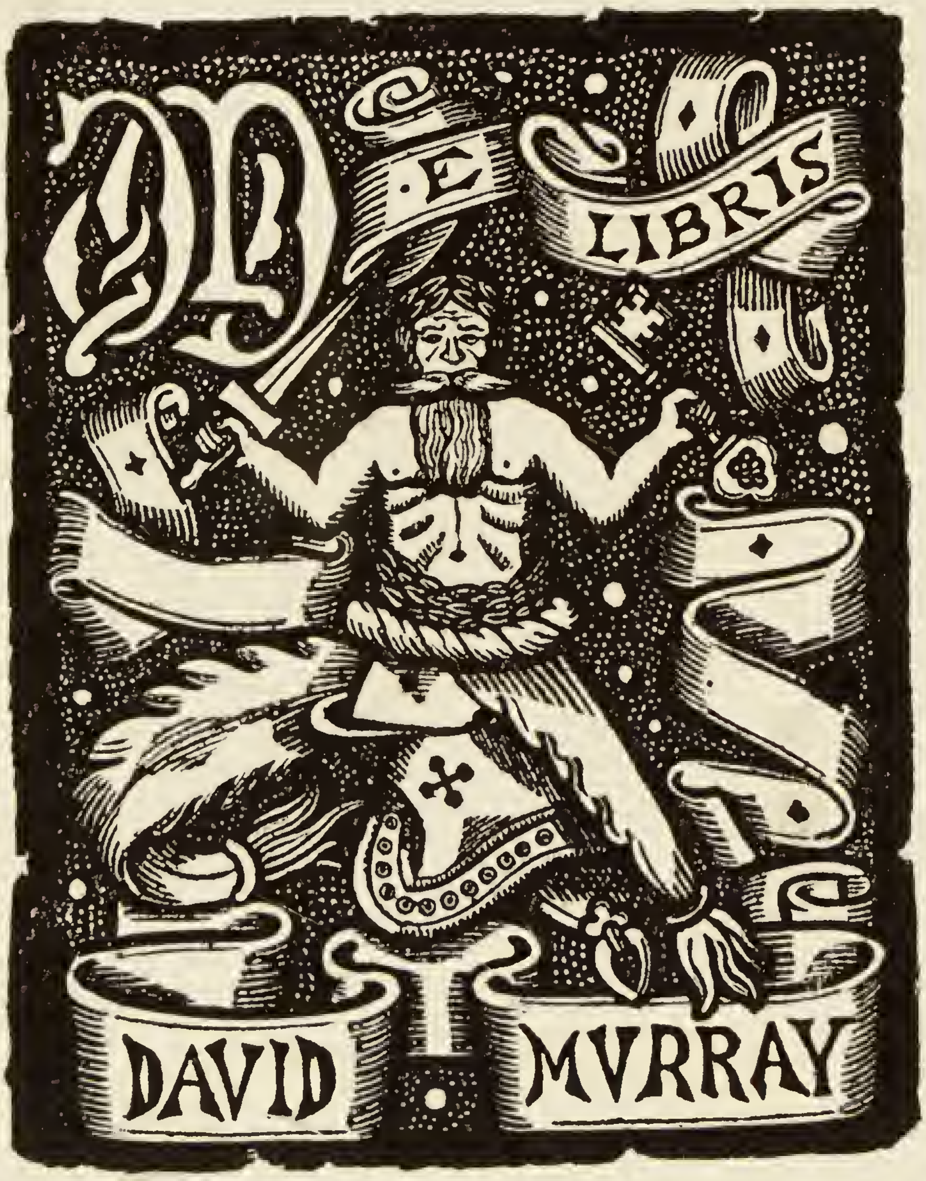
TCHISON (Graham) ESSAYS on UNEXPLAINED PHENOMENA, containing new Views re-
ng the CAUSE of CENTRIFUGAL FORCE in PLANETARY MOTION ; the RADIATION of CALORIC,
he CENTRAL HEAT of the EARTH, with REFUTATIONS of many existing Opinions on these
ects, post 8vo. *cl.* (*name cut out of title, and back slightly torn*) ; *scarce*, 8*s* 6*d* *Glasgow*, 1838
astronomical and meteorological paradox, based on 'the repellent force subsisting between particles of the caloric,
so between the homogeneous particles of other imponderable bodies'. It was unknown to Prof. de Morgan.



Thomas Brown Esq
of Waterhaughs
With the Author's Compliments

David Murray
Glasgow.

A TREATISE

ON THE

CAUSES AND PRINCIPLES

OF

METEOROLOGICAL PHENOMENA.

ALSO,

TWO ESSAYS;

THE ONE

ON MARSH FEVERS;

THE OTHER

ON THE SYSTEM OF EQUALITY, PROPOSED BY MR OWEN OF NEW LANARK, FOR AMELIORATING THE CONDITION OF MANKIND.

BY GRAHAM HUTCHISON.

GLASGOW:
ARCHIBALD FULLARTON AND CO.;
MACLACHLAN & STEWART, EDINBURGH; ORR & SMITH, LONDON.
MDCCCXXXV.

GLASGOW:
FULLARTON AND CO., PRINTERS, VILLAFIELD.

TO THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE,

THE FOLLOWING TREATISE

ON THE

CAUSES AND PRINCIPLES OF METEOROLOGICAL PHENOMENA,

WITH THE TWO ANNEXED ESSAYS,

IS RESPECTFULLY DEDICATED BY

THE AUTHOR.

PREFACE.

Among all the Sciences, there is none which so frequently, or so generally obtrudes itself upon the attention of mankind, or is so often the subject of conversation, as that of which we are about to treat. But though this be the case, there is no science which presents such a list of familiar phenomena, that have hitherto defied all attempts at explanation. In the following Treatise, a variety of new views and explanations of meteorological phenomena are advanced; and it is principally on account of these, that this volume is printed.

Besides the Treatise on the Causes and Principles of Meteorological Phenomena, two Essays are likewise published. One of these contains a compilation of the more important facts and information, collected from various sources, relative to Marsh Fevers, a knowledge of which may be useful, in preserving the lives of many who have occasion to visit our colonial settlements in the East or West

Indies, or other countries where such diseases prevail. The other is an Exposition of the Erroneous Nature of Mr Owen's Plan for ameliorating the Condition of Mankind, accompanied with Observations on the Measures and Policy calculated to promote that desirable Object. These two Essays are selected from a variety of papers read by the Author to a Literary Society in Glasgow, in consequence of their affording a greater amount of information on the subjects of which they profess to treat, than any of the others.

CONTENTS.

ERRATA.

Page 18, line 22, for "5 inches," read "4 inches."
— 448, — 25, for "Gottingen," — "Gottenburg."

INTRODUCTION.

METEOROLOGY is that department of Physical Science which treats of Atmospheric Phenomena. It comprehends a considerable number of subjects ; and each of these contains a great variety of details. Several of the phenomena to be treated of are so mutually dependent upon each other, that with a view to explain their causes, it is difficult to decide upon what arrangement ought to be adopted. For instance, variations of temperature on different parts of the earth's surface disturb the atmospheric equilibrium, and give rise to aerial currents ; while, on the other hand, aerial currents, according as their direction is from a cold or a warm climate, produce important alterations in the temperature of the incumbent atmosphere. Again, variations in the atmospheric temperature are principally instrumental in the formation and dissolution of clouds ; while, on the other hand, the existence of clouds reduces the temperature of the subjacent atmosphere during day and summer, while it augments it during night and winter. In such cases, it is immaterial which subject is first considered.

Perhaps the following arrangement is as well calculated to render the various phenomena treated of intelligible, as any other. Without farther introduction, we proceed with our subject.

ON THE CAUSES AND PRINCIPLES

OF

METEOROLOGICAL PHENOMENA.

CHAPTER I.

OF THE ATMOSPHERE—ITS HEIGHT—DENSITY—COMPOSITION—COLOUR—CAPACITY FOR MOISTURE—DIMINUTION OF TEMPERATURE UPON ASCENDING PERPENDICULARLY, TOGETHER WITH AN EXPLANATION OF THE MORE OBVIOUS REASONS WHY THE ATMOSPHERE IS USUALLY MORE OR LESS UNDERSATURATED WITH HUMIDITY.

The globe which we inhabit is every where surrounded by a thin, invisible, elastic fluid, called the air, or atmosphere. From the duration of twilight, arising from the refraction of light, and also from calculations relative to the rarefaction of air, considered in conjunction with the effect of increasing cold as we ascend, in diminishing the elasticity of gaseous particles, it has been concluded, that the atmosphere of our earth cannot extend to a greater altitude than 45 miles above the level of the sea. About this degree of elevation, it has been estimated, that the gravity of the air will equal its elasticity; and this of itself will limit and prevent its farther extension. Farther, from the expansibility of air by means of heat,

considered in conjunction with the similarity of the mean barometrical pressure at the level of the sea in all latitudes, which indicates a sameness in the absolute amount of air incumbent over all latitudes, it has been concluded, that the greatest elevation of the atmosphere is in the equatorial, or warmest regions of the earth; and that its elevation gradually diminishes towards the polar, or coldest regions.

Air, when the barometer stands at 30 inches, and the thermometer at 60°, (which, in similar estimates, is always understood when nothing different is mentioned,) is 828 times lighter than water; and its specific gravity in such circumstances is usually denoted 1.000. Owing to the inferior aerial strata having to bear the weight of all those above, the density of the atmosphere has been found, in ascending perpendicularly, to diminish in the ratio of compression. The density, therefore, decreases in geometrical progression, while the height increases in arithmetical progression. From this circumstance it is obvious, that though the atmosphere extends to the height of 45 miles, the great bulk of it is contained within a comparatively limited distance from the earth's surface. It has been estimated, that on reaching the perpendicular altitude of 18,000 feet above the level of the sea, one-half of the atmosphere is surmounted. And, accordingly, a barometer at such an elevation would stand at 15 inches, while underneath, at the level of the sea, it stood at 30 inches.

Though the air we breathe was formerly considered a simple substance, it is now known to be a compound. Its constituents are nitrogen, oxygen, and carbonic

acid gases, and aqueous vapour, existing in a state, not of chemical combination, but of uniform intermixture, with each other. Of the gases, nitrogen and oxygen are its principal elements; the proportions being 79 parts of the former to 21 of the latter, by bulk; and 76.701 to 23.299, by weight. The proportion of carbonic acid is very small, varying according to different estimates, (for it is difficult to ascertain its precise amount,) from $\frac{1}{800}$th to $\frac{1}{1000}$th part of the other two gases. The proportions of the two principal gaseous elements of the atmosphere, nitrogen and oxygen, are the same relatively to each other in all latitudes, and, so far as observations have extended, at all heights, and in all places, where there is a free communication with the external air. But the proportion of carbonic acid relative to that of the other two gases is said to vary, being greater in summer than in winter, and during night than during day.

Owing to the variations in the quantity of carbonic acid in the atmosphere, its presence there was by some considered accidental. Saussure, however, ascertained that it existed in the atmosphere at the top of Mont Blanc, 15,662 feet high, in similar proportion as at the level of the sea. And Gay Lussac, who ascended at Paris, in a balloon, to the height of 22,960 feet, the greatest ever reached by man, analyzed air which he had obtained at that elevation, and found that the relative proportions of its gaseous elements, including the carbonic acid, were the same as at the surface of the earth. These observations have sufficiently established the fact of carbonic acid being a

permanent constituent of the atmosphere, notwithstanding its alleged variableness in quantity.

The relative proportion of aqueous vapour contained in the atmosphere is extremely variable, and is regulated in a great measure by the temperature of the air. It appears from Saussure's experiments, that a cubic foot of air, of the temperature of 66°, is able to hold, in invisible solution, 11 or 12 grains of water. Now, as the weight of the cubic foot of air at the above temperature, and under an atmospheric pressure equal to 30 inches of mercury, is about 570 grains, air at the temperature of 66° is capable of dissolving about a 50th part of its own weight of water. After making allowance for the rapid diminution in the capacity of the air for moisture, as its temperature lowers in ascending perpendicularly, it has been estimated, that in Great Britain, during summer, the weight of water present in the atmosphere frequently amounts to $\frac{1}{60}$th of the whole; whereas, during winter, it often does not exceed $\frac{1}{300}$th of the whole. In warm latitudes, the weight of aqueous vapour contained in the atmosphere is frequently double what it is, during summer, in Great Britain; and, on the other hand, in the polar regions, during winter, the proportion is extremely small, in comparison with what it ever is in the temperate climate of Britain. Dr Dalton supposes that the medium quantity of vapour held in solution by the atmosphere may amount to $\frac{1}{70}$th of its bulk.

The mean pressure of the atmosphere seems to have undergone no change since observations were first made with the barometer. From a meteorological journal kept by the celebrated Mr Locke, at Oates,

in Essex, the mean annual pressure for the year 1692, was 29.58, which is nearly the mean height observed in every quarter of the globe at present, after making allowance for the altitude of the place of observation above the level of the sea. A similar remark applies to the permanency of its constituent proportions. No alteration, in this respect, has taken place since air has been correctly analyzed. Hence, notwithstanding the absorption, and evolution of the several elements of the atmosphere, constantly going on during the growth and decay of vegetables; and likewise during the support of combustion, and animal life, and all other chemical processes, whether natural or artificial; it is inferred, that the amount of atmosphere surrounding the globe, and the proportions of its several elements are permanent quantities, regulated by fixed though unknown laws; and resulting probably from properties permanently inherent in the atmospheric materials themselves. If heat be the principal agent in determining the proportion of matter that exists in the gaseous state around the earth, (as it probably is, though its influence in this respect may be also assisted by light and electricity,) the permanency in the amount of atmosphere must be ascribed to the mean temperature of the globe, considered as a whole, being continually the same; and to the attractive forces mutually subsisting between the atmospheric elements and heat, and all other terrestrial materials, being also permanently the same.

The blue colour of the sky was formerly supposed to be owing to the visibility of the atmosphere when viewed in mass; but from later observations it ap-

pears, that what was attributed to the whole compound, belongs exclusively to one of its constituents, viz. the aqueous vapour; and it is now thought that its gaseous elements are altogether colourless and invisible. Upon this point Dr Thomson says, "the blue colour of the sky is occasioned by the vapours which are always mixed with air, and which have the property of reflecting the blue rays more copiously than any other. This has been proved by the experiments which Saussure made with his cyanometer at different heights above the surface of the earth. He found that the colour of the sky always corresponds with a deeper shade of blue the higher the observer is placed above the earth's surface. Consequently, at a certain height, the blue will disappear altogether, and the sky appear black, that is to say, will reflect no light at all." Saussure accordingly found that the sky, when viewed perpendicularly upwards from the top of Mont Blanc, appeared nearly jet black, that is, reflected almost no light. This he ascribed to the extremely small amount of aqueous vapour existing in the atmosphere above that elevation. Dr Thomson likewise remarks, that the colour of the sky becomes always lighter in proportion as the amount of vapours mixed with the air increases, and I may be allowed to add, in proportion as they are less thoroughly dissolved thereby. Hence it is evident that the colour of the sky is produced by them.

As the meteorological phenomena of most frequent occurrence, and which, on that account, it is of most importance to understand, depend upon the relation subsisting between the temperature of the atmosphere

and the amount of aqueous vapour which it is capable of holding in a state of invisible solution, we shall here notice the principal facts explanatory thereof.

If air contained in a close vessel be allowed to communicate freely with a surface of water beneath, and contained in the same vessel, it is usually found that a portion of the water slowly disappears, by assuming the state of invisible vapour intermixed with the air in the vessel. If the temperature remain stationary, evaporation by and by ceases. If the temperature be augmented after evaporation has ceased, an additional portion of the water begins again to disappear by vaporization. If, on the other hand, the temperature be gradually lowered after evaporation has ceased, a portion of the water previously vaporized is gradually precipitated; and if the reduction of temperature be stopped at any point, deposition of moisture simultaneously ceases. And so on for every increment, or decrement of temperature. The utmost amount of water which air at any given temperature can hold in invisible solution, is called its capacity for moisture; and air so loaded with moisture, is said to be saturated therewith. The point of saturation, in reference to its indicating the degree of atmospheric humidity, at which, during a gradual reduction of temperature, the precipitation of moisture in the forms of dew, mist, or clouds, commences, is also called the dew point, or point of deposition or precipitation.

As the capacity of air for moisture varies with its temperature, the attention of philosophers has been directed to ascertain the relative ratio of variation. Different results have been obtained by different ex-

perimenters, which it is unnecessary separately to particularize. All we mean to do, in order to communicate a general understanding of this, and other meteorological phenomena, where the results obtained by different experimenters vary, is to adopt either one of the results, or a mean estimate of the more important of them, as an approximation to the truth. Judging from the experiments which have been made, it appears, that while the temperature of air increases in arithmetical progression, its capacity for holding moisture in invisible solution increases in geometrical progression, or very nearly so. And for every increment of temperature amounting to about 23.4 degrees by Fahrenheit's scale, the capacity of air for moisture is doubled. Thus, if the capacity of air for moisture be denoted 1 at the temperature of zero, it will be 2, or double the zero capacity at the temperature of 23°.4 ; 4, or quadruple the zero capacity at the temperature of 46°.8 ; 8, or eight times the zero capacity at the temperature of 70°.2 ; and 16, or sixteen times the zero capacity at the temperature of 93°.6, &c.

It has been ascertained that the temperature of the atmosphere in all latitudes diminishes on ascending perpendicularly from the level of the sea; but the rate of diminution, as determined by different observers, and even by the same observers at different times and places, varies greatly. It appears also that the rate of diminution is more rapid in summer than in winter. Of this latter fact Sir John Leslie, in the article Climate, in the Supplement to the Encyclopædia Britannica, gives the following satisfactory explana-

tion:—"Since the heat derived from the sun is chiefly accumulated at the surface of the earth, the changes of temperature which take place through the year in the elevated strata of our atmosphere must evidently be less than what are experienced below. The lofty tracts of air remote from the primary scene of action, preserve nearly an equable temperature, and scarcely feel the extreme heat of summer, or winter's frost. In ascending the atmosphere, the decrease of warmth is hence more rapid in the fine season, and more slow in the darkened period of the year."

Besides the cause above assigned for the different results obtained by different experimenters, there are obviously a variety of other modifying circumstances, the separate or conjoint influence of which, in consequence of their variable and uncertain nature, it is impossible accurately to appreciate. The more important of these are as follow: 1st, The communication upwards, whether by calorific radiation, reflection, conduction, or aerial *convection*,* of the ever-varying diversity of temperature, to which land and water relatively to each other, are in different climates subjected, during day and night, and the different seasons of the year. 2d, The transportation of air from warmer, or from colder latitudes, by means

* *Convection* is a very suitable term introduced by meteorologists to denote the power which one body has in carrying another along with it. Thus clouds and vapours are carried along with the atmospheric current; and aerial convection in the text above, means, the power of air, when its specific gravity is diminished by heat, to carry that heat along with it in its ascent.

of atmospheric currents. 3d, The evolution of heat which accompanies the formation of clouds; and, on the contrary, its absorption, when clouds and mists are converted into invisible vapour.

There is even some reason to believe, that the average ratio of decrease of temperature is not the same at different altitudes. Playfair remarks that the decrease seems to be somewhat slower, but not very considerably, as we ascend. And Dr Prout, in his 'Bridgewater Treatise,' says, " some late researches have rendered it probable, that while, at different heights, the rate of the decrease of temperature is uniform, the rate of altitude increases constantly, and according to laws very similar all over the world; that is to say, supposing the first 252 feet are equal to one degree; the second degree will be equal to 255 feet; the third to 258; the fourth to 261;" &c. Humboldt found in ascending, that the ratio of decrement was less in the region of the air where clouds were formed, than what it was nearer the surface of the earth; and that it again became greater at a higher altitude. This he properly ascribed to the evolution of heat, which accompanies the formation of clouds. From the various results obtained by different persons at different times and places, with a view to determine this point, meteorologists are now unanimous in adopting one degree of Fahrenheit as the mean rate of decrement for every 300 feet of perpendicular ascent, and extending to all attainable altitudes. Hence we see, that from this cause, the mean temperature of the atmosphere at the top of a mountain 3000 feet high, should be 10 degrees lower than at its base.

And at the top of Mont Blanc, which is 15,662 feet high, the mean temperature should be $52\frac{1}{5}$ degrees lower than at the level of the sea in the same latitude.

Two causes have been assigned for the diminution of temperature in ascending perpendicularly from the earth's surface. The first is, that owing to the permeability of the atmosphere to the solar rays, the heat thereby imparted to the earth, is absorbed, and accumulated at, and near its surface; and only slowly recommunicated to the incumbent atmosphere. Hence, it is supposed, that as a less and less amount of the solar heat accumulated at the earth's surface is imparted to the atmospheric strata, according as they become more distant from the seat of accumulation; the temperature of the atmosphere, in receding perpendicularly from the earth's surface, must undergo a gradual diminution.

The preceding explanation is exceedingly unsatisfactory, as will be evident by referring to analogical phenomena. Thus when the general temperature is increasing, whether in consequence of radiation from the sun, a fire, or any heated body, it is found, that the surface of all solids exposed to such calorific radiation, acquires a higher temperature, that is, heats faster, than the air around them, and through which the heat radiates. And on the contrary, during the time that the temperature is upon the decline, the surface of all solids stands at a lower temperature, that is, cools faster, than the air around them. Now this case is exactly analogous to the one under consideration. The surface of the earth is alternately heating and cooling during day and night, and also

during summer and winter. When heating during day or summer, its surface is warmer than the air immediately incumbent; but when cooling during night or winter, it is colder. And from Dr Wells' observations it appears, that the excess of coldness of the earth's surface during night or winter, as well as the excess of heat during day or summer, is slowly communicated to the air immediately incumbent, and in proportion to its proximity. Thus it was found, that during clear calm nights, the temperature of the atmosphere, instead of sinking, actually rose, and that with considerable rapidity, from the surface of the earth to the height of 220 feet above it; and how much higher was not ascertained, in consequence of observations not being extended to greater altitudes. When this fact is considered in conjunction with the circumstance of the rapidity with which the temperature of the higher atmospheric strata, would be assimilated to that of the lower by means of aerial convection, were there no counteractive cause, it is obvious, that the explanation above given, though it may account for slight variations in the ratio, in which temperature decreases upon ascending perpendicularly during day and night, and during summer and winter, does not at all account for the constant mean rate of decrement observed in ascending perpendicularly all over the surface of the globe, and extending to all attainable heights.

The second cause assigned in order to explain the fact under consideration, is the increase of capacity for absorbing caloric, which air acquires, when subjected to a gradual diminution of aerial pressure, ac-

cording as the amount and weight of the superincumbent atmosphere diminishes in ascending perpendicularly. Upon this point, Dr Prout, in his Bridgewater Treatise, page 270, says: "Dr Dalton, and afterwards Sir John Leslie more completely, have attempted to show, that the equilibrium of heat in an atmosphere is obtained when each of its molecules, or in other words, when the same weight of air, in the same perpendicular column, is possessed of the same quantity of heat. Now, since atmospheric pressure diminishes with the height, according to a certain law, it is obvious, that the same weight of air, at the surface of the earth, and in the higher regions, will occupy very different spaces. But since the absolute quantity of heat is exactly the same in both portions, it is likewise obvious, that in the higher regions of the atmosphere, from the increased capacity of the air for heat, the quantity of latent heat is augmented, while the quantity remaining sensible becomes less. Hence the temperature of the air diminishes as we ascend, exactly in the proportion that its latent heat, that is to say, its capacity for heat as produced by rarefaction, increases." Dr Thomson, in his work on Heat and Electricity, says: "It has been experimentally ascertained, that as the volume of air increases, its specific heat augments in the same proportion." And in a subsequent passage, he says: "The same weight of air, at all elevations above any place, contains exactly the same quantity of heat. So that if a quantity of air were suddenly transported from an elevated region to the level of the sea, its density would be continually increasing during its descent, while its specific heat

would diminish in the same proportion, and, when it reached the level of the sea, its temperature in consequence would be just as high as that of other portions of air in the same latitude and elevation. Air, therefore, does not feel cold in consequence of falling from an elevated situation, though this be an opinion commonly entertained, but in consequence of its being suddenly transported from a more northerly to a more southerly situation."

The preceding hypothesis seems to afford a perfectly satisfactory explanation of the fact under consideration, were it not for an objection suggested by an experiment, which we will here relate. If a thermometer be suspended in the exhausted receiver of an air-pump, or in a Torricellian vacuum, it stands at the same degree of temperature as one suspended externally in the unrarefied atmosphere; and variations of temperature affect both thermometers in the same manner, and ultimately to the same degree. It is true, that upon exhausting the air suddenly, by means of an air-pump, a delicate thermometer suspended in the receiver sinks; but then it very soon regains its former temperature without any re-admission of air. Now, judging from analogy, this latter circumstance seems to indicate, that the permanent reduction of temperature as we ascend in the atmosphere, is not owing to the increased capacity of air for heat when its compression or density is diminished; for, if such were the case, a correspondingly permanent reduction of temperature should be exhibited, one would think, by a thermometer in an exhausted, or partially exhausted receiver.

No attempt seems to be made by any writer whose

works I have consulted, to reconcile the phenomena exhibited during the performance of the experiment stated above, with the explanatory hypothesis quoted from Prout and Thomson. Nevertheless, from the corroboration which the hypothesis receives, from the circumstance of the temperature of the air actually diminishing as we ascend, in the proportion that its capacity for heat, as produced by rarefaction, increases; and also from this circumstance explaining what seems to be overlooked, viz. the otherwise inexplicable fact of the warmer air below having no tendency to change places with the colder air above, so long as the mean rate of decrement is preserved, I am disposed to think, that the increased capacity of the air for heat, according as the superior aerial compression diminishes, is either the true cause, or rather a constant and necessary concomitant of the true cause of the mean rate of decrement of temperature, upon ascending perpendicularly from the level of the sea.

When the humidity or dryness of the atmosphere is mentioned, reference is made, not to the absolute amount of moisture in the air, but to the amount in relation to its capacity. The more undersaturated the atmosphere is, the drier it is said to be; and the stronger is its influence in promoting evaporation from moist surfaces. On the contrary, the nearer it approaches to saturation, the more humid it is; and the less its influence in promoting evaporation.

The parent source from whence the atmosphere, when undersaturated, derives a supply of aqueous vapour, is the ocean; and the process by which it is supplied is called evaporation. It is true that from every

moist land surface evaporation also takes place. But as the land itself derives its moisture from the atmosphere, in the forms of rain, dew, &c.; and as a considerable proportion of the moisture which is precipitated upon the land is returned to the ocean by means of rivers, it is obvious that the land would soon become thoroughly and permanently dried up, were it not supplied with humidity from the ocean, through the agency of evaporation and atmospheric currents.

Various attempts have been made to determine the annual quantity of water which the land derives from the ocean through the agency of atmospheric currents. Some have endeavoured to ascertain this point by calculating the amount of water evaporated from land at a mean temperature, relative to the estimated annual amount thereupon precipitated; and others have made estimates of the amount of water annually returned to the ocean by means of rivers, relative to the quantity precipitated from the atmosphere upon the land drained by these rivers. Dr Thomson estimates the annual amount of water (including dew, which he estimates at 5 inches,) precipitated upon the land, and reduced to a mean for the whole surface of Great Britain, to be about 36 inches; while the quantity evaporated may be about 32 inches; $\frac{8}{9}$ths therefore of the water annually precipitated upon this island, he supposes, is again evaporated from the land, and only $\frac{1}{9}$th is returned to the ocean by means of rivers; and of course only $\frac{1}{9}$th is derived from the ocean through the agency of atmospheric currents. Dr Dalton, on the other hand, estimated the proportion of water annually carried off by the rivers in England

and Wales, as amounting to 13 inches. The difference between these two estimates show how little dependence can be attached to them. Besides, in different latitudes, and even in different countries in the same latitude, the proportion evaporated relative to what is condensed, must, for obvious reasons, vary extremely; and though the proportions applicable to Great Britain could be ascertained, they would be applicable no where else. In inland champaign countries, in temperate latitudes, where little rain falls, almost the whole water precipitated upon the land will be again evaporated from it; and hardly any of it returned to the ocean by means of rivers. On the other hand, in countries bordering upon the sea; and in small, or moderately sized islands, particularly where the declivity from the central parts of the land towards the sea is considerable; and where the rains fall in great quantities at particular seasons, with long intervals of dry weather; the greater part of the water precipitated from the atmosphere upon the land will be returned to the ocean by means of rivers, and only a moderate proportion of it evaporated. In short, the circumstances of different countries are in this respect so various, that no rules universally applicable can be laid down. In general, however, provided other things be equal, the proportion of water precipitated upon the land which is returned to the ocean by rivers, will be greater the colder and the calmer the climate is; also greater in proportion as the rains are more copious for the latitude, and restricted to particular seasons, so that the intervals of dry weather, (when, in consequence of the dryness of the

ground, no evaporation is going on,) may be the longer; and likewise greater, in proportion as the land is better fitted for allowing the water to run off speedily, whether in consequence of natural declivities, or artificial draining; and *vice versa*.

Evaporation, as we before stated, is the name given to the process by which the atmosphere is replenished with humidity from moist surfaces underneath, when, from causes hereafter to be mentioned, it has become undersaturated. Now the laws by which evaporation is regulated are as follow:—

1. It goes on with greater rapidity according as the incumbent atmosphere is more undersaturated with humidity; and with diminishing rapidity as it approaches saturation, at which point it ceases altogether.

2. Supposing the atmosphere undersaturated to a given extent, evaporation proceeds with greater rapidity according as the evaporating surface becomes warmer. And supposing the atmosphere saturated, evaporation will, notwithstanding, commence so soon as the temperature of the evaporating surface is raised higher than that of the atmosphere. In fact, the point of saturation at which evaporation ceases, is determined, not by the temperature of the air, but by that of the evaporating surface. But as the temperature of the air regulates the amount of vapour which it can hold in invisible solution, all moisture evaporated by means of heat applied to the evaporating surface after the air is saturated, is condensed into the visible form of mist, so soon as it is cooled down to the aerial temperature by intermixture with the incumbent air.

3. Supposing the atmosphere undersaturated to any given extent, evaporation proceeds with greater rapidity according as the velocity of the wind increases, for, in such circumstances, fresh undersaturated portions of air are successively brought more rapidly in contact with the evaporating surface.

Though air in communication with water has a tendency to become saturated with moisture, yet when hygrometric observations are made, it is generally found that the atmosphere is more or less undersaturated; and accordingly, that a greater or less reduction of temperature must ensue before any precipitation of humidity can take place. The cause of this, and also of the circumstances which tend to bring the atmospheric humidity up to the point of saturation, and sometimes beyond it, so that precipitation ensues, will be obvious, by considering the vicissitudes of temperature to which the atmosphere is subjected during the alternate succession of day and night, and the different seasons of the year; and also during the progressive movements of atmospheric currents over land and water of different degrees of elevation, and of different temperatures.

During night, the capacity of the atmosphere for moisture, in consequence of the diminution of temperature which then ensues, is considerably less than during day. Hence, though the atmosphere during day be considerably undersaturated with moisture, it gradually approximates this degree of dampness as the temperature declines upon the approach of night. And provided it reaches the point of saturation previous to the coldest period of the night, the farther

sinking of temperature causes precipitation of moisture into the visible forms of dew, mist, and cloud; and consequently does not increase the atmospheric dampness, hygrometrically speaking; for in hygrometry, no estimate is made of moisture, except it be held in invisible solution by the atmosphere. Now, supposing the atmosphere to have reached the point of saturation during the coldest period of the night, it follows, that, as its temperature again rises, and its capacity for humidity increases, upon the return, and during the advance of day, the atmosphere must gradually become more and more undersaturated. And this result is not restricted to the atmosphere incumbent upon the land: for even over the ocean, (though in a less degree than over the land,) the atmosphere usually becomes hygrometrically drier during day, in consequence of evaporation not being sufficiently copious to supply the air with moisture so rapidly as its capacity for it increases with the then advancing temperature. These observations explain the reason why night air is usually damper, and to those whose constitutions are injured by a humid atmosphere, more unwholesome than that of day. They also explain the reason why more moisture is converted into clouds and mist, and precipitated upon the surface of the earth in the forms of dew and rain during night, than during day: and, upon a similar principle, more during the fall of the year, when the temperature and capacity of the air for moisture are upon the decline, than during the opposite season, when the temperature and capacity of the atmosphere for moisture are advancing.

Again, when the wind blows from a cold towards a warmer climate, which, as will be subsequently explained, is its prevailing direction over the earth, though not in this climate, the air, by communicating with a progressively warmer surface, has its temperature and capacity for aqueous vapour more rapidly increased, than it is supplied with humidity by evaporation. This explains the reason why northerly winds, in northern latitudes, are usually drier, and of course promote evaporation from all moist surfaces more rapidly than those of equal thermometric temperature from the south. The piercing, refrigerating, and withering influence commonly ascribed to north and north-east winds in this island, particularly during the spring of the year, is owing, not so much to their absolute thermometric coldness, (though that too has its influence,) as to their undersaturated state of dryness, and consequently to their greatly increased effect in abstracting heat from the human body, and from all other moist surfaces, by accelerating evaporation.

When the wind, on the contrary, blows from a warm towards a colder latitude, and has its temperature slowly reduced by communicating with a progressively colder surface underneath, its capacity for aqueous vapour is simultaneously diminished. Hence the air in such circumstances, though previously much undersaturated, gradually approaches the point of saturation. And if this hygrometric condition of the atmosphere goes on increasing, aqueous vapour begins at length to be precipitated into the visible state of clouds and mist, and subsequently descends to the earth in the forms of rain, snow, &c. This is one rea-

son why southerly winds, which in our northern latitude blow from a warm towards a comparatively cold climate, are usually damper and more prolific of clouds and rain than those from a northerly direction.

Again, when the wind blows from the ocean in summer, particularly during its latter half, the atmosphere becomes gradually undersaturated as it advances over the land; and, upon the same principle, when it blows in the contrary direction, viz. from the land towards the ocean, during the opposite season of the year, it in like manner gradually becomes undersaturated as it approaches the ocean, and *vice versa.* The reason of these results will appear obvious by comparing the annual range of temperature which the surface of the land undergoes with that of the ocean.

In temperate latitudes, the annual range of heat to which the surface of the Atlantic ocean is subjected, is limited to about 9 degrees of Fahrenheit; whereas, that of the surface of the land, in corresponding latitudes on the continent of Europe, at no great distance from the ocean, may be about 90 degrees. The temperature of the ocean varies, therefore, no more than about 4½ degrees from the mean for the latitude, during the coldest and warmest periods of the year; whereas, that of the land varies about 45 degrees from the mean annual temperature. In like manner, during day and night, the temperature of the surface of the ocean undergoes little variation, compared to that of the land. And it may be laid down as a general law, that in a given latitude, the nearer any place is to the ocean, the more limited is the range of temperature both daily and annually; and, on the con-

trary, the farther from the ocean, the more extensive is the range of temperature.

Now, as the temperature of the surface of the ocean varies but very little throughout the year, from the mean degree of heat for the latitude, compared to that of the land; and as the temperature of the earth's surface, whether it be land or water, is gradually communicated upwards to the incumbent atmosphere, it follows, that an atmospheric current from the ocean towards the land, during the summer half of the year, or from the land towards the ocean, during the winter half, is analogous to the instance previously given, of a wind blowing from a cold towards a warmer climate. In both cases, the air in its progress, by communicating with a warmer substance underneath, has its temperature and capacity for moisture gradually increased. And hence, unless counteracted by other causes, must become more or less undersaturated, and, accordingly, less liable to give birth to clouds and rain.

From the same premises, it follows, on the other hand, that an atmospheric current from the land towards the ocean, during the summer half of the year, or from the ocean towards the land, during the winter half, is analogous to the other previously given instance, of a wind blowing from a warm towards a colder climate. In both cases, the air in its progress, by communicating with a colder surface underneath, has its temperature and capacity for moisture gradually diminished; and hence, unless counteracted by other circumstances, must have a tendency to get saturated with moisture, and, accordingly, to become more liable to give birth to clouds and rain.

These observations, in part, explain the reason why a wind blowing from the ocean towards the land, during the warmest period of the year, so seldom brings rain, in comparison with what it does during the coldest season. They also explain the reason why a wind blowing from the land towards the ocean, during summer, may sometimes be found saturated with moisture upon reaching the sea-coast, or within a short distance of land; whereas, when the wind blows from the same direction during winter, it may be expected almost invariably to be much undersaturated, and, accordingly, to bring fair weather.

Again, when the wind blows over mountain ranges, or elevated lands, its temperature and proportionate capacity for moisture is reduced, as already stated, by one degree for every 300 feet of perpendicular ascent. Now, supposing, for the sake of illustration, that the height of the elevated lands is 3000 feet, and that the atmospheric current before reaching them is saturated with humidity, it is obvious, that the lower stratum of air, in surmounting such an elevation, must undergo a reduction of temperature equal to 10 degrees; and, accordingly, moisture is converted in such quantity into clouds, (which partly discharge themselves in rain upon the earth's surface, and partly pass onwards with the wind at a great altitude,) that after the same stratum of the atmospheric current has crossed the elevated regions, and regained its former low level and temperature, it ought to be 10 degrees of temperature undersaturated. This explains the reason why the atmosphere is less humid, and why less rain falls to the leeward, than to the windward of high lands and mountain ranges.

Upon similar principles, when winds blow over extensive tracts of dry land, where they encounter a variety of the circumstances already enumerated, which rob the air of a portion of its moisture, without being proportionally replenished from a watery surface underneath, a greater or less degree of atmospheric undersaturation is the usual result. Hence the reason why near the coast on continents, (as is exemplified in the United States of North America,) the air is more humid, and more rain falls when the wind blows from the ocean, than when it blows from the opposite direction, over an extensive tract of land. And, according to the same principle, it may be laid down as a general law, that the more remote any place is from the ocean, provided other circumstances be equally favourable, the more undersaturated with moisture ought to be the usual character of the atmosphere, and the smaller the annual amount of rain.

It may be here noticed, that when speaking of air becoming undersaturated in consequence of passing over extensive tracts of land, it supposes the surface of such land, or at least a large proportion of it, to be dry. When the surface of land is thoroughly wet, and its temperature is as high as that of the ocean, evaporation proceeds with as great rapidity from its surface as from that of the ocean. And supposing a thoroughly moistened land surface to be warmer than that of the ocean, as is usually the case in the end of summer, and beginning of autumn, evaporation from its surface should go on more rapidly than from that of the ocean. Besides, the saline ingredients of the ocean render its waters less liable to evaporation; so

that even from this cause alone, a land surface thoroughly moistened with fresh water, is supposed to supply aqueous vapour to an undersaturated atmosphere, more speedily than the surface of the ocean. In forming meteorological conclusions regarding the circumstances calculated to produce atmospheric dryness, or dampness, it should therefore be always recollected, that a wind blowing over land thoroughly moistened by previous rainy weather, is not necessarily a dry wind, unless some of the other circumstances before stated, such as blowing from a cold direction, or over elevated lands, render it so. In reality, such a wind, so far as dryness or dampness is concerned, is much the same as though it blew from the sea: the hygrometric condition of the atmosphere in both cases, being usually very little above the point of saturation. These observations explain the reason why, after continued wet weather, the chance of rain, other things being equally favourable, is usually as great when the wind blows from the land, as when it blows from the ocean. They also explain the reason why, when the wind changes, and blows from the sea, in continental countries previously thoroughly dried by long droughts, the first rains usually fall near the coast. And, provided the wind from the sea continues prevalent, gradually as the land gets moistened to a greater and greater distance from the sea, so as to become an evaporating surface, capable of replenishing an undersaturated atmosphere with humidity, so does the rainy weather extend itself farther into the interior.

Having thus given an enumeration of the more obvious circumstances which produce variations in the

hygrometric condition of the atmosphere, it need hardly be remarked, that those circumstances may be observed at different times and places acting either in union with, or in opposition to, each other. In the former case, their effect becomes more powerful; in the latter, the influence of one cause neutralizes that of another. In endeavouring, therefore, to account for the conditions of the atmosphere in reference to dryness and dampness, the circumstances favourable to the one state, must be balanced against those favourable to the other. For according as there happens to be a more favourable combination of circumstances for producing the one effect or the other, so is the result more certain; and the general character of the weather more strongly marked; and *vice versa.*

When it is considered, that the hygrometric dampness of the atmosphere is prevented from ever exceeding the point of saturation by the precipitation of moisture which then commences; and, in accordance with our previous observations, that a variety of causes tending to reduce it below that point, are in constant operation in one quarter or another; we have a sufficient explanation of the fact of air, though in free communication with the ocean, and other collections of water on the earth's surface, being usually more or less undersaturated. Hence the reason why water exposed to the atmosphere usually evaporates with more or less rapidity; a result which could not take place, were the air previously saturated with moisture, and its temperature as high as that of the water.

From the hygrometric observations made with a view to ascertain the state of the atmosphere as to dryness in various situations, and at different heights above the level of the sea, it has been calculated, that the mean point of deposition for the whole atmosphere surrounding the globe, is about 6 degrees below the mean temperature. Of course, it is to be understood, that some proportion of the atmosphere is at all times fully saturated with humidity; but that this is balanced by a larger proportion more or less undersaturated beyond 6 degrees. The general result therefore is, that the atmospheric temperature requires to sink on an average 6 degrees, before moisture held in invisible solution by the air, begins to assume the visible forms of mist and clouds; and also, before deposition of humidity in the form of dew can commence.

From observations made in the years 1815 and 1818 it appears, that the mean quantity of moisture in the atmosphere on any given day, corresponds, in this climate, nearly with what would produce complete saturation at the minimum temperature of that day. Owing, however, to variations in the weather from wet to dry, and the contrary, this coincidence does not take place every day; but holds very nearly in the means of the whole year. Thus the mean point of deposition for each month in the year, corresponds very nearly with the mean minimum temperature of the days throughout the month.

Proceeding upon the principle of the mean point of deposition being 6 degrees below the capacity of the mean temperature, the following table,* showing

* Hygrometry,—Edinburgh Encyclopædia.

the mean amount of aqueous vapour, reduced to the state of water contained in the atmospheric columns for every 5 degrees of latitude from the equator to either pole, has been calculated.

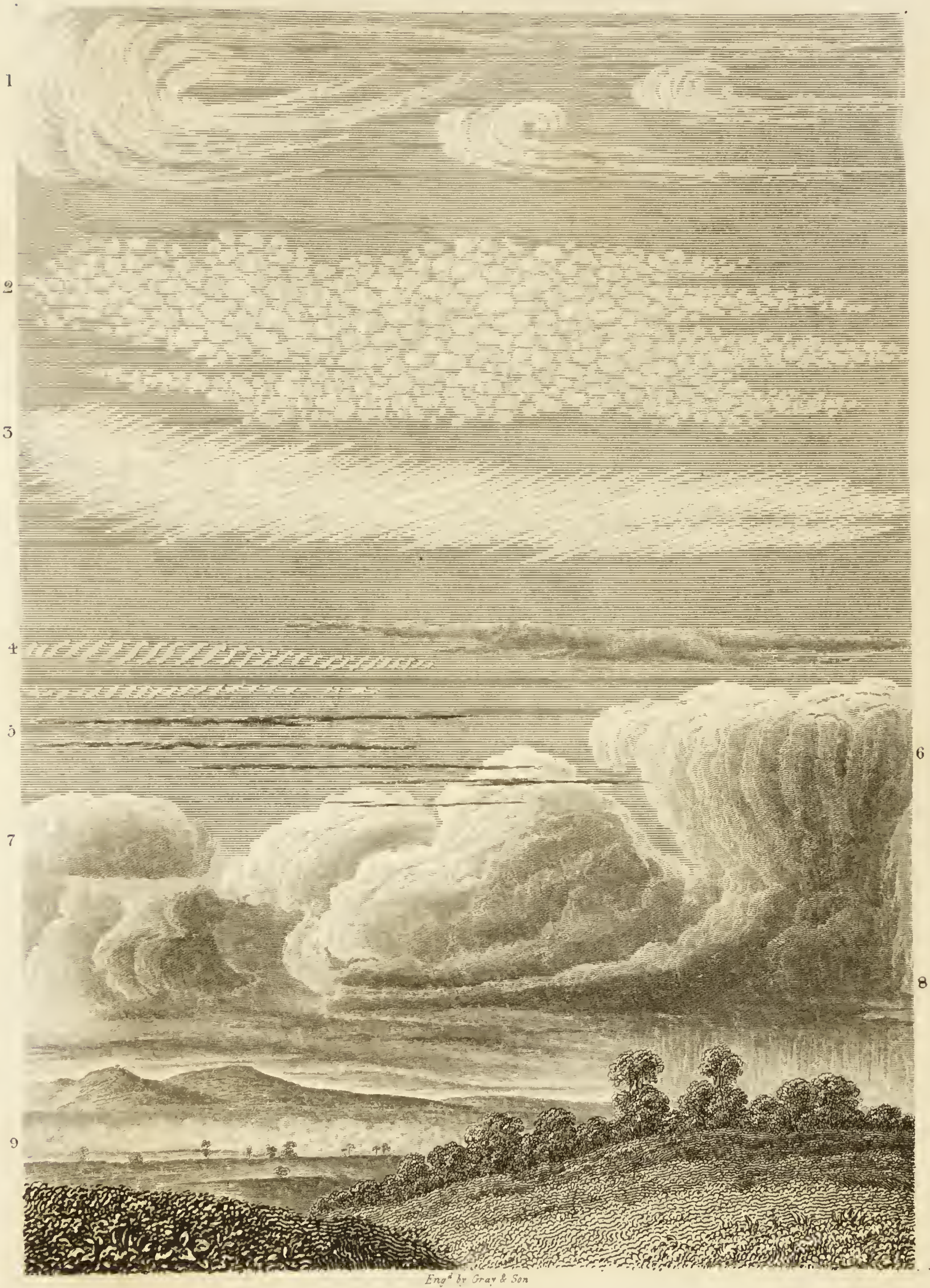
Latitude.	Mean Temperature.	Column of Water equal to Column of Vapour in Inches.	Latitude.	Mean Temperature.	Column of Water equal to Column of Vapour in Inches.
0	85.	8.315	50	53.3	2.882
5	84.6	8.112	55	48.8	2.468
10	83.4	7.809	60	44.5	2.124
15	81.4	7.326	65	40.6	1.854
20	78.7	6.717	70	37.3	1.647
25	75.4	6.037	75	34.6	1.495
30	71.5	5.315	80	32.6	1.391
35	67.2	4.611	85	31.4	1.332
40	62.7	3.968	90	31.	1.313
45	58.	3.385			

By the preceding table it appears, that if the whole aqueous vapour contained in the air at the equator were condensed, and precipitated, it would cover the surface of the earth only to the depth of 8.315 inches; and that the amount diminishes more rapidly than the mean temperature as we advance towards either pole.

In intertropical and temperate latitudes, it is probable that the calculations in the preceding table are tolerably near the truth. But they are obviously very erroneous in high latitudes, in consequence of the mean temperature being taken at greatly above what it ought to have been, as determined, in recent years, by actual observation. It may be also mentioned, that the above table, as well as all other hygrometric estimates, gives merely the amount of aqueous vapour held in a state of invisible solution by the atmosphere,

and does not include the amount previously precipitated, and suspended in the air in the visible forms of clouds and mist. If the proportion of vapour condensed into the visible forms of mist or clouds were to be estimated, in conjunction with what is held in invisible solution, the air would have to be stated as being frequently oversaturated with moisture. In wet weather, for instance, when hygrometers indicate that the air is saturated with humidity, the existence of clouds indicates a degree of atmospheric oversaturation, to the extent of moisture which the clouds contain. The phrase oversaturation is, therefore, in this point of view, correct enough; and to avoid circumlocution, we shall on many occasions make use of it. At the same time, as the amount of aqueous vapour contained in the forms of mist and clouds cannot be accurately ascertained, and does not affect the condition of the atmosphere, so as to indicate, when tested by hygrometers, a degree of dampness beyond the point of saturation, in estimates such as the one we have been considering, it is perhaps as well omitted altogether.

HOWARD'S NOMENCLATURE OF CLOUDS.



1 The Cirrus or Curlcloud
2 The Cirrocumulus or Sondercloud
3. 4. 5. Various forms of the Cirrostratus or Wanecloud
6. The Cumulostratus or Twaincloud
7. The Cumulus or Stackencloud
8. The Nimbus or Raincloud
9. The Stratus or Fallcloud

CHAPTER II.

OF THE CLASSIFICATION OF CLOUDS, AND THE PHENOMENA EXHIBITED DURING THEIR FORMATION, TOGETHER WITH A DESCRIPTION OF THE VARIED APPEARANCES WHICH THE DIFFERENT DENOMINATIONS PRESENT, AND OF THE CHANGES WHICH THEY UNDERGO.

NOTWITHSTANDING the infinitely diversified figures and appearances which clouds present, they have been arranged by Howard into seven classes, and designated as follows :—The *Cirrus*, the *Cumulus*, the *Stratus*, the *Cirro-cumulus*, the *Cirro-stratus*, the *Cumulo-stratus*, and the *Cumulo-cirro-stratus*, or *Nimbus*. Of these, the three first, viz. the *Cirrus*, the *Cumulus*, and the *Stratus*, are considered primary forms. The fourth and fifth, viz. the *Cirro-cumulus*, and the *Cirro-stratus*, are considered intermediate forms, from their presenting appearances somewhat between those of the primary clouds, of which their names are respectively composed. The sixth and seventh, viz. the *Cumulo-stratus*, and the *Cumulo-cirro-stratus*, or *Nimbus*, are considered compound, from being apparently formed by the union and transformation of other denominations of cloud.

Rather than trust to my own very limited observations enabling me to describe the progressive formation, together with the varied appearances and changes which the different classes of clouds above enumer-

ated undergo, I will borrow largely, and frequently without altering the language, from the article in the Supplement to the Encyclopædia Britannica, entitled " Cloud." Adhering then to the usual arrangement, we shall now proceed to describe,

1. The *Cirrus*, (see fig. 1.) or *Curl-cloud.* The most usual form of this species of cloud resembles a distended lock of hair. It consists of separate fibrous-looking, or hair-like stripes of cloud, parallel to each other, and not unfrequently curled, or slightly bent towards one, and more rarely, towards both extremities. In appearance, it is the thinnest, the lightest, and the most rarefied of all the denominations of cloud; and in conformity with its appearance, it occupies a more elevated region in the atmosphere than any of the other kinds, floating usually, according to Dalton, from 3 to 5 miles above the level of the sea.

This species of cloud is continually changing its figure. After a continuance of clear weather, the *cirrus* first makes its appearance in the form of a white thread stretched across a portion of the sky. To this line others are successively added laterally, so as ultimately to present the appearance of a number of parallel white threads of cloud. This form is called the *linear cirrus.* At other times, in addition to the above, lines of the same kind are sent off in oblique or transverse directions, so that the cloud presents the appearance of net-work. This species is called the *reticulated cirrus.* " The comoid *cirrus,* vulgarly called by the country people of England, the mare's-tail cloud, is however the proper *cirrus.* It has the appearance of a distended lock of white hair, or of a

bunch of wool pulled out into fine pointed ends, from whence it has derived its name, comoid. This form of the *cirrus* is most commonly an accompaniment of a variable state of the atmosphere, and often forebodes wind and rain. In very changeable weather, the direction of the tails of this kind of *cirrus* varies considerably in the course of a few hours. When the tails have a constant direction towards the same point of the compass for any considerable time, it has been frequently observed that a gale has sprung up from the quarter to which they had pointed."

2. The *Cumulus*, (see fig. 7.) or *Stacken-cloud*, or cloud of day, as it is sometimes called, is characterized by a flattened base, and a heaped or cumulated superstructure. It floats at a much lower level than the *cirrus*, varying perhaps from 3000 feet to two miles above the level of the sea. In its appearance it is the most picturesque of all the denominations of cloud, and when opposed to the sun, reflects from its piled-up sides a brilliant white colour, as pure as that of snow.

" The best time for viewing the progressive formation of the *cumulus* is in fine settled weather. If we then observe the sky about the time of sunrise, or soon afterwards, we shall see small specks of cloud here and there in the atmosphere. These often appear to be the result of small gatherings, or concentrated points of the *stratus* or evening mist, which, rising in the morning, grows into small masses of cloud, while the circumjacent atmosphere becomes clearer."

" As the sun rises these clouds get larger,—two or

three which are near each other coalesce,—and at length a large cloud is formed, which, assuming a cumulated and irregularly hemispherical shape, has received the name of *cumulus* or *stacken-cloud*. This may properly be denominated the cloud of day, as it usually subsides in the evening, in a manner which forms the exact counterpart to its formation in the morning. It breaks up into small fragments and evaporates, and is succeeded again by the *stratus* or *fall-cloud*, which has been called the cloud of night by some writers, on account of the period in which it prevails."

"There are some varieties in the forms of the *cumulus* which deserve particular notice, as they seem to be connected with electrical phenomena. In some kinds of fine weather, when these clouds form soon after sunrise, increase through the day, and subside in the evening, they are of a more hemispherical form than when they occur in changeable weather. When these well-formed *cumuli* prevail during many days together, the weather is settled, and the atmospherical electrometer has been observed not to vary much in its indications. These *cumuli* are whitish-coloured, and reflect a fine strong silvery light when opposed to the sun. The *cumuli* which are seen in the intervals of showers are more variable in form; they are more fleecy, and have irregular protuberances. Sometimes they are of a blackish colour, like the clouds which the sailors call *scud*, and at other times they seem of a tuberculated form. *Cumuli* may, at any time, increase so as to obscure the sky, and they then generally inosculate, and begin to assume that

density of appearance which characterizes the twain-cloud, or *cumulo-stratus.*"

3. The *Stratus*, (see fig. 9.) or *Fall-cloud*, or cloud of night, as it is sometimes called, from the time it usually makes its appearance, are the meteorological names given to fogs and mists, which, in extensive sheets, chiefly during night, cover the earth's surface, and disappear usually in the morning with the advancing temperature of day. Sometimes, particularly in calm weather, and during the coldest period of the year, when, owing to the obliquity of the sun's rays, his influence is not sufficiently strong to dissipate them, this species of cloud rests upon the earth's surface, perhaps for a week or a fortnight without intermission.

The best opportunity for observing the formation of the *stratus*, is on a fine still evening, after a hot day in the end of summer or beginning of autumn, at which time this species of cloud is very prevalent. " We shall then observe, that as the *cumuli*, which have prevailed through the day, decrease, a white mist forms by degrees close to the ground, or extends only for a short distance above it. This cloud arrives at its density about midnight, or between that time and morning, and it generally disappears after sunrise. The *stratus* has often been found positively electrified, and its component particles do not wet leaves or other substances connected with the earth. It has been supposed that the earth below it, and probably the air above it, contained a negative countercharge. The *stratus* should be distinguished from that variety of the *cirro-stratus*, or wane-cloud, which

looks much like it in external appearances, and which has usually a similar state of electricity with the earth. The criterion whereby we may judge, to which of the two modifications to refer a mist, is, that the *stratus* does not wet objects it alights on, but the *cirro-stratus* moistens every thing."

4. The *Cirro-cumulus*, (see fig. 2.) or *Sonder-cloud*, consists of small, roundish, well-defined masses of clouds, separated, or sometimes only nearly separated, from each other, and closely arranged in extensive horizontal beds. This cloud has more resemblance to the *cumulus* than to the *cirrus*. In fact, it seems to consist of small, imperfectly or flatly formed *cumuli* arranged in horizontal beds.

" This cloud is subject to some varieties in the size and figure of its orbicular masses, and in their nearer or more distant approximation to each other. Its most striking feature is observable before or about the time of thunder-storms in summer. The component *nubeculæ* are then very dense in their structure, very round in their form, and in closer apposition than usual, (see fig. 2.) This kind of sonder-cloud is so commonly a forerunner of storms, that it has been frequently spoken of by poets as a tempestuous prognostic. In rainy and variable weather, a variety of this cloud appears, strikingly contrasted with the above-mentioned kind, being of a light, fleecy texture, and its *nubeculæ* having no very regular form. Under these circumstances, it is sometimes so light and flimsy in its texture as to approach very nearly to the nature of the *cirro-stratus*. Sometimes this kind of *cirro-cumulus* consists of *nubeculæ* so

small as scarcely to be discernible; the sky seems speckled with innumerable little round white, and almost translucid spots. The *cirro-cumulus* of fair summer weather is of a middle nature, neither being so dense as the stormy variety, nor so light as the one last described. Its *nubeculæ* vary in size, and in the degree of their proximity. In certain kinds of fine dry weather, with light gales of north and easterly wind, small detachments of *cirro-cumulus* rapidly form and subside again, which do not lie in one plane, but, in general, these clouds are in horizontal arrangement. The formation of *cirro-cumulus* is either spontaneous, that is, unpreceded by any other cloud; or, 2d, it may result from the changes of some other modification. Thus the *cirrus* or *cirro-stratus* often changes into *cirro-cumulus*, and *vice versa*. When this cloud prevails in summer, we may, in general, anticipate an increase of temperature; and, in winter, it often precedes the breaking up of a frost, and indicates warm and wet weather. In warm weather during summer, several extensive beds of this cloud, ranged in different altitudes, and viewed by moonlight, have a very beautiful and picturesque appearance, and have been compared by poets to a flock of sheep at rest. The *cirro-cumulus* either subsides slowly, as if by evaporation, or it changes into some other modification of cloud.

5. The *Cirro-stratus*, (see fig. 3, 4, and 5.) or *Wane-cloud*. The form of this cloud, which is least apt to be confounded with that of other denominations, is often seen on fine summer evenings, when it presents the appearance of a bed or layer of cloud,

of considerable length, but neither broad nor deep, and seemingly stationary at a great altitude above the earth's surface, (see fig. 5.) " All the varieties of this cloud are characterized by shallowness, or great horizontal extent, in proportion to their vertical depth; so that when the *cirrus*, or any other cloud, is observed to assume this form, we may generally expect that it will end in a *cirro-stratus*. The *cirrus*, for example, after having existed some time in the higher regions of the atmosphere, often descends lower; its fibres become more regularly horizontal; and it puts on, by degrees, the character of the wane-cloud. The *cirrus* more frequently changes to the *cirro-stratus* than the *cirro-cumulus* does, and the *cirro-cumulus* more frequently than the *cumulus*.

" The *cirro-stratus* being once formed, sometimes re-assumes the character of the modification from which it originated, but more frequently it evaporates by degrees, or, by inosculating with some other modification, produces the twain-cloud, and eventually falls in rain.

" The *cirro-stratus* seldom remains long in the same form, but is observed to be constantly subsiding by degrees; hence it has been called the wane-cloud from the old English verb *to wane*, to decline, or waste away. There are many varieties in the figure of the *cirro-stratus*, some of which are more transitory than others. Sometimes this cloud is disposed in wavy bars or streaks, in close horizontal apposition, and these bars vary almost infinitely in size and shape. A flat, and nearly horizontal cloud, composed of such streaks, is very common, particularly

in variable weather, in summer. The bars, which compose this variety, are generally confused in the middle, and are more distinct towards the edges, (see fig. 3.) A variety not unlike this is seen on fine summer evenings, and constitutes what has been denominated the Mackerel-back Sky. It is often very high in the atmosphere. We have observed that, on ascending lofty mountains, the apparent distance of this cloud seems hardly diminished, while the *cumulus*, or stacken-cloud, has been sailing along on a level with the point of observation, or even below it. Another common variety of *cirro-stratus* differs from the last in being one plane and long streak, thickest in the middle, and wasting away at its edges. This, when viewed in the horizon, has the appearance of fig. 5. It often seems to alight on the summits of the *cumulo-stratus* as represented in the plate; and in these cases, the density of the large twain-cloud increases in proportion as these long wane-clouds form, and evaporate on their summit; a circumstance which looks as if the great density of the cloud depended on the inosculation and subsequent intermixture of the two different modifications with each other. The result of this intermixture, and the consequent density of the cloudy mass, is eventually the formation of the *nimbus*, and the fall of rain. Another principal variety of the *cirro-stratus*, is one which consists of small rows of little clouds curved in a peculiar manner. It is called the *Cymoid Cirro-stratus*, and it is a sure indication of stormy weather, (see fig. 4.) Immediately below this in the plate, is the representation of another less perfectly formed, having more of the

character of the sonder-cloud. It is a variety often produced when a large *cumulus* passes under a long line of *cirro-stratus*, like that in fig. 5, and is also a sign of variable and stormy weather. The last variety of *cirro-stratus* to be mentioned, is that large and shallow veil of cloud, which extensively overspreads the sky, particularly in the evening, and during the night, and through which the sun and moon but faintly appear. It is in this cloud that those peculiar refractions of the sun and moon's light, called Halos, Mock-suns, &c., usually appear, and which is the surest prognostic we are acquainted with of an impending fall of rain or snow. To these principal varieties of the *cirro-stratus* others less frequent might be added; but, as their forms are almost innumerable, every meteorologist must observe them for himself. The usual termination of the *cirro-stratus* is, by forming an intimate union with some other cloud to produce rain. In general, therefore, the prevalence of the wane-cloud is always a sign of a fall of rain or snow. At other times, this cloud evaporates, or changes into some other modification, as previously observed."

6. The *Cumulo-stratus*, (see fig. 6.) or Twain-cloud, is a compound of the *cumulus* and the *cirro-stratus;* the *cirro-stratus* being either intermingled with the *cumulus*, or widely extending its base, so that while the base is flat, and united like the *cirro-stratus*, the superstructure resembles large *cumuli*, rising from the base in the forms of detached mountains and rocks.

" The *Cumulo-stratus* may be always regarded as

a stage towards the production of rain, and it frequently forms in the following manner :—The *cumulus*, which in common passes along in the current of the wind, seems retarded in its progress,—increases in density,—spreads out laterally,—and at length overhangs the base in dark and irregular protuberances. The change to the *cumulo-stratus* often takes place at once in all the *cumuli* which are near to each other; and their bases uniting, while the superstructures remain asunder, rising up with mountain-like or rocky summits, the whole phenomena has a fanciful appearance. The change from *cumulus* to *cumulo-stratus* is often preceded by the *cirro-stratus*, or some other of the lighter modifications, coming over in an upper current, and alighting on the summit of the *cumulus*. Long lines of wane-cloud often appear for a length of time attached transversely to the summits of the twain-cloud, and give them the appearance of being transfixed by shafts, (see fig. 6.) *Cumuli* sometimes meet together, and begin to be arranged along with joined bases, without acquiring the dense black colour of the *cumulo-stratus*, and, as the change is gradual, we may view the cloud in an intermediate state. Twain-clouds vary somewhat in appearance. Those in which hard hail showers and thunder storms form, look extremely black before the change to rain, and have a most picturesque but menacing aspect, as they are seen slowly coming up with the wind. The *cumulo-stratus* sometimes evaporates, or changes again to *cumulus*, and sometimes it forms itself spontaneously, without the precurrence of any other cloud, and disappears again. But, in general, it ends at last

in the *nimbus*, and falls in rain. Frequently, in a long range of these clouds, one part changes into *nimbus*, and rains, while the other remains a *cumulo-stratus*, (see fig. 8.) But this is not frequently the case. Having given this sketch of the modifications, it must be observed, that masses of cloud sometimes appear hardly referable to any of them; but even then, if watched long enough, they will be found to put on sufficient of the character of some of the modifications to be registered under its name."

7. The *Cumulo-cirro-stratus* or *Nimbus*, or Rain-cloud, is that cloud, or aggregation of clouds, from which rain is falling. It usually presents the appearance of a horizontal layer of aqueous vapour, over which clouds of the *cirro-stratus* kind are spread; while other clouds of the *cumulus* form enter it laterally, and from beneath.

" Any of the six above described modifications may increase so much as to obscure the sky, without ending in rain, before which, the peculiar characteristic of the rain-cloud may always be distinguished. The best manner of getting a clear idea of the formation of the *nimbus*, is by observing a distant shower, in profile, from its first formation to its fall in rain. We may then observe the *cumulus* first arrested, as it were, in its progress, then a *cirrus*, or *cirro-stratus*, may appear to alight on the top of it. The change to *cumulo-stratus* then goes on rapidly, and this cloud, increasing in density, assumes that black and threatening appearance which is a known indication of rain. Shortly afterwards, the very intense blackness is changed for a more grey obscurity, and this is the

criterion of the actual formation of water, which now begins to fall, while a *cirriform* crown of fibres extends from the upper parts of the clouds, and small *cumuli* enter into the under part. After the shower has spent itself, the different modifications appear again in their several stations; the *cirrus, cirro-stratus*, or perhaps the *cirro-cumulus*, appears in the higher regions of the air, while the remaining part of the broken *nimbus* assumes the form of a flocky *cumulus*, and sails along in the current of wind which is next the earth. When large *cumulo-strati* begin to appear again, they indicate a return of the rain; and these processes are constantly going on in showery weather, when the rapid formation and destruction of rain-clouds goes on, and is attended by the other modifications in succession, in the manner above described. In continued rainy days, we cannot observe the upper parts of the *nimbus*, which extends for miles over large tracts of country; but we have no doubt that the same processes go on slower and on a larger scale in continued rainy weather, which are more conspicuous in the rapid and partial formation of showers."

CHAPTER III.

ON THE CAUSES AND PRINCIPLES WHICH DETERMINE THE FORMATION OF CLOUDS.

It has been already stated, that the capacity of the air for holding moisture in invisible solution, increased and decreased in geometrical progression, while its temperature increased and decreased in arithmetical progression. But though the precipitation of moisture into the visible form of mist or clouds, may arise either from a reduction in the temperature of the atmosphere, or from a reduction in reference to its capacity, still as there are a variety of circumstances in which such reductions of temperature occur, for the sake of being better understood, we shall arrange them under the four following heads :—

1. *When a diminution of the atmospheric temperature unaccompanied by atmospheric rarefaction, or transportation, takes place.*

2. *When a diminution of the atmospheric temperature arising from atmospheric rarefaction takes place.*

3. *When a diminution of the atmospheric temperature, arising from the transportation of air from a warm to a cold climate by the agency of winds, takes place.*

4. *When an intermixture, and consequent reduc-*

tion to a mean temperature, of different portions of air of previously different temperatures, takes place.

If any one, or any combination of these circumstances happen to occur, when the atmosphere is previously saturated with humidity; or supposing the atmosphere previously somewhat undersaturated, if they take place to such an extent as to produce oversaturation, a precipitation of moisture into the visible form of cloud or mist, is the necessary consequence.

We shall treat of these four causes of the formation of clouds separately in their order as above.

A diminution of the atmospheric temperature independent of, and unaccompanied either by rarefaction, or transportation of air, takes place, in the gradual transition from the maximum temperature of day, to the minimum of night; and from the maximum temperature of summer, to the minimum of winter.

Of these two transitions, individually considered, the former, viz. from the maximum temperature of day to the minimum of night, produces, in a given number of hours, a greater reduction of temperature than the latter. Its influence, however, in this respect though greatest, is chiefly limited to the atmospheric strata near the ground. Hence the cloud most frequently, and most extensively formed by it, occupies a similar low position, and is denominated, in meteorological language, the *stratus* or fall-cloud, or sometimes the cloud of night, from the time it usually makes its appearance. It comprehends, and is commonly applied exclusively to those low creeping fogs or mists, which, on clear still nights, cover plains,

hollows, &c.; but under this title we mean to treat of all fogs and mists whatever.

The causes and principles which determine and regulate the formation of the *stratus*, are, with some additions hereafter to be noticed, the same as those which, according to Dr Wells, determine and regulate the deposition of dew. These we shall endeavour to explain. From Dr Wells' observations, it appears, that a thermometer, laid upon grass during calm clear nights, exhibited an atmospheric temperature lower, sometimes by as much as 10 degrees, than one suspended in the air four feet above the grass. It was farther found by the observations of Mr Six of Canterbury, that the atmospheric temperature continued gradually to rise according to a diminishing ratio, in ascending perpendicularly above four feet, so that at the altitude of 220 feet, (and observations were not extended higher,) the atmosphere, on favourable nights, exhibited a thermometric temperature as much as 10 degrees higher than it did at four feet above the ground.

From the circumstance of the reduction of temperature being always greater, in proportion as the surface of the ground immediately under was better fitted for radiating caloric, Dr Wells demonstrated that the phenomena exhibited by the above thermometric observations during night, were produced by the escape of heat from the earth's surface by radiation, being then more rapid than the supply by conduction from underneath. This circumstance induced a considerable degree of coldness on the earth's surface, beyond what the atmosphere a few feet above

exhibited, before the supply of caloric became equal to the amount that escaped, and the progressive increase of temperature which the air manifested upon ascending perpendicularly to the height of 220 feet, arose from this superior coldness being slowly communicated upwards to the incumbent atmospheric strata, with diminishing effect, according as they were farther removed from the surface of the ground.

On cloudy nights little or no reduction of temperature close to the earth's surface took place, beyond what was exhibited four feet above it. This Dr Wells ascribed to the partial interruption given to the radiation of heat from the earth's surface by clouds, the effect of which was, that the supply of heat from underneath by conduction, without the accelerating aid of any sinking of temperature on the earth's surface, then became equal to the amount that escaped by radiation. That this was the true explanation he proved by the fact, that, upon the supervention of a cloud, the thermometer placed upon the grass very soon rose to the same, or nearly the same temperature, as the one four feet above it; and that after the cloud had passed away, the thermometer on the grass very soon sunk to its former temperature, while the other remained almost stationary. He also demonstrated the accuracy of the above explanation, by producing analogous results by means of artificial awnings. Thus, by covering the thermometer laid upon the grass with a piece of paste-board, shaped like the roof of a house, and open to the atmospheric current at both ends, the reduction of temperature, as indicated by the thermometer, was prevented in the same manner

as it was by the supervention of clouds. A similar effect was produced by an awning of thin muslin, and in a less degree by the shade of trees, houses, or other elevated objects, which, to any extent, limited or reduced the view of the sky, as seen from the place where the thermometer was laid.

On windy nights, Dr Wells found that no reduction in the atmospheric temperature close to the ground took place, beyond what was exhibited by a thermometer four feet above it. And in fact, other things equal, the sinking of the atmospheric temperature close to the ground was greater, in proportion as the air subjected to observation was calmer, and from its local position, such as being on a low-lying plain, or in a slight hollow, less liable to be displaced by slowly progressing aerial currents. This effect of wind, and the similar one produced by slopes, such as the sides of hills present, in consequence of their allowing the cooled, and, therefore, the specifically heavier aerial particles nearest the ground to roll downwards, Dr Wells very properly ascribed to the circumstance of uncooled portions of air from above, being rapidly and successively brought into contact with the radiating surface; the temperature of which was prevented from sinking, in consequence of the caloric which those uncooled portions of air communicated.

These and similar observations Dr Wells successfully applied to explain the phenomena of dew. In order to ascertain the amount of dew deposited, he usually employed swandown, which, being one of the best radiators of caloric, indicated, by means of the

sinking of a thermometer laid upon it, compared with one suspended four feet above it, the degree of coldness induced upon the earth's surface by radiation; and, by the additional weight it acquired, indicated the amount of dew deposited upon it. By varying his experiments, with a view to prevent mistakes as to the source from whence the dew was derived, he proved that it neither resulted from evaporation from the earth's surface, nor from the exudation of plants. And by comparing the amounts deposited, with the reduction of temperature induced upon the earth's surface by radiation, he satisfactorily demonstrated that it was a deposition from the atmospheric strata nearest the ground, arising from the coldness therefrom communicated.

The preceding observations enable us to understand the leading phenomena connected with the most frequent formation of the stratus. When upon the approach, or during the continuance of night, the temperature of the aerial particles nearest the ground sinks, in consequence of the radiation of heat from the earth's surface, to the extent required to produce the slightest degree of oversaturation, the deposition of dew commences. And the formation of the stratus begins to make its appearance, so soon as the coldness thus induced upon the earth's surface is slowly propagated upwards in sufficient intensity to produce atmospheric oversaturation.

By way of illustrating this department of our subject, we will state a variety of the phenomena presented during the formation of this species of cloud, and subjoin the explanation.

1. The *stratus* begins to form close to the surface of the ground, and gradually extends itself upwards, and usually does not exceed a very limited altitude. This, agreeably to the foregoing principles, is owing to the fact of the coldness induced upon the earth's surface by the escape of radiating heat, being soonest communicated in sufficient intensity to produce oversaturation to the aerial particles nearest the ground; and from that degree of coldness, being afterwards so slowly communicated upwards, as only to reach a very limited height before the return of day.

2. The *stratus* during its formation is densest nearest the surface of the ground, and gradually diminishes in density upwards. This, as was demonstrated by the thermometric observations of Dr Wells, is owing to the coldness induced upon the earth's surface by radiation, being communicated to the incumbent aerial strata with less diminished intensity, according to their greater proximity to the ground.

3. Provided other circumstances be equally favourable, (which is always understood,) the deposition of dew, and the formation of the *stratus*, commence earlier in the evening, according as the hygrometric condition of the lower atmosphere is nearer the point of saturation, before the radiation of heat from the earth's surface, upon the approach of evening, begins. This is owing to a smaller depression of temperature being then requisite to produce atmospheric oversaturation; and, consequently, the radiation of heat from the earth's surface effects this depression earlier in the evening, because having less to do, it does it in less time.

4. On certain nights seemingly favourable, from the calmness of the air, and the clearness of the sky, to the deposition of dew, and the formation of the *stratus*, neither dew nor mist make their appearance. This, which is of frequent occurrence in inland dry countries, is owing to an unusual dryness, or under-saturated condition of the atmosphere; the reduction of temperature effected by radiation not being sufficient, in such cases, to reduce the capacity of the air for moisture, below the point of saturation.

5. The *stratus* may frequently be seen during night overspreading meadows and level grass fields, to the depth of a foot or two, while the surface of a gravel road, passing through the midst of these, remains perfectly free from this species of cloud. This, as demonstrated by Dr Wells' observations, is owing to the surface of meadows and grass fields being better adapted for radiating caloric, and, consequently, for exhibiting a greater degree of thermometric depression of temperature during night than gravel roads. Hence the reason that over meadows and grass fields the temperature of the air may be reduced below the point of saturation, and precipitation of moisture into the form of mist may accordingly take place; while over the gravel road the temperature of the air may not be sufficiently depressed to produce oversaturation; and, accordingly, no mist will there make its appearance: and so of all other analogous cases.

6. In the summer half of the year, the *stratus* formed during night disappears in the morning, or early in the day; whereas, during winter, fogs frequently continue for many successive days and nights

without intermission. The reason of this is, that, during the summer half of the year, the heat of the sun upon the return of day, is sufficient to dissipate fogs formed during the coldness of night, by reconverting them into invisible vapour; whereas, during winter, owing to the obliquity with which the sun's rays then fall upon the earth, the small amount of heat thereby communicated during day, is not unfrequently insufficient to accomplish this object.

7. In equally serene evenings, the *stratus* is more prevalent in the beginning of autumn than in the end of spring, or beginning of summer; and, in general, its formation is more extensive, and of more frequent occurrence, in the fall of the year; and, in fact, so long as the temperature is declining, than it is in the opposite season of the year, when the temperature is advancing. The reason of this is, that, in the former case, the declination of temperature from the maximum of summer to the minimum of winter, co-operates with the diurnal sinking of temperature, upon the approach of evening, in producing atmospheric oversaturation; whereas, in the latter case, the advancing temperature from the minimum of winter to the maximum of summer, in some degree counteracts the tendency to atmospheric oversaturation, occasioned by the diurnal sinking of temperature upon the approach, and during the continuance of night.

We will now state cases in which a *stratus*, or fog, is formed in circumstances so far disconnected with those in which dew makes its appearance, that a simultaneous deposition of this commodity may, or may not, take place.

The formation of a *stratus* or mist of this kind, may result from a general sinking of the atmospheric temperature, either totally disconnected with, or only partially assisted by the upward propagation of the nocturnal coldness induced upon the earth's surface by calorific radiation. Such fogs, like all others, only make their appearance, in this climate, in still weather; and occur most frequently when the temperature is rapidly declining upon the approach, or during the depth, of winter. Their formation may commence at any altitude above the earth's surface, where the atmosphere, upon the reduction of its temperature, becomes first oversaturated, upon which condition their existence, like that of all other fogs, depends; and their perpendicular thickness, which is sometimes great, is necessarily co-extensive with the depth of atmosphere that becomes oversaturated. Damp low-lying flat countries, such as Holland, where the air is frequently loaded with moisture, and where the sinking of temperature in the fall of the year is considerable, are, in accordance with our previous observations, most subject to this kind of fog.

Fog of a different kind, or rather arising from a different cause, (for from whatever source or union of sources originating, they all equally consist of moisture existing in some imperfectly understood state, between invisible vapour and water;) fog, I say, arising from a different cause from any of those which precede, frequently makes its appearance in still weather over the surface of water, and nowhere else. This species of fog may usually be seen floating over the surface of canals, and deep pools, in a calm morn-

ing, after a clear frosty night, upon the first introduction of cold weather in the fall of the year. It arises from the surface of water being warmer than the incumbent atmosphere. The temperature of the moisture evaporated in such circumstances from the warm watery surface underneath, sinks upon intermixing with the colder atmosphere immediately incumbent; and so soon as the air thus supplied with humidity becomes oversaturated, this species of fog begins to show itself. Vapour seen issuing from the steam-pipe of a steam-engine, or from the mouth of a kettle of boiling water, is analogous in its formation to this kind of fog. The vapour, upon intermixing with the cold air as it issues from the steam-pipe, is suddenly condensed in such quantities as to produce atmospheric oversaturation, and thus forms the visible mist which is commonly called steam. But as this mist gets separated farther from the steam-pipe from whence it issued, it is gradually dispersed, and reconverted into the invisible state by evaporation, and aerial diffusion, and solution.

The preceding observations sufficiently explain the nature and origin of this description of fog, and what follows will explain the laws by which its individual density varies and is regulated.

1. Supposing the evaporating surface of a given extent, and the atmospheric temperature at a given point, the higher the temperature of the water is above that point, the faster will evaporation go on from its surface, and, of course, the greater will be the amount of vapour formed and condensed in a given time.

2. The stiller the atmosphere is, the less liable will the condensed vapour be to be blown away, and dissipated.

3. The nearer the hygrometric condition of the atmosphere is previously to the point of saturation, the less of the evaporated moisture will disappear by aerial diffusion and solution.

According therefore as a more favourable combination of these three circumstances happen to occur, so is this species of fog more certain to make its appearance, and also to exhibit a greater degree of density; and *vice versa.*

The fog or haze which makes its appearance over the sea when its surface is warmer than the incumbent atmosphere, is identical in the causes and principles of its formation with that which we last described. This condition of the temperature of the atmosphere, in reference to that of the subjacent ocean, may occur, when a wind blows for a short time over a sea surface from the polar towards the equatorial regions, and more particularly when it blows during winter, from an extensive, and more northerly cold land surface towards the ocean, and a warmer latitude. The cold atmosphere thus transported, by remaining incumbent upon a comparatively warm sea surface, at length becomes saturated with the moisture therefrom evaporated. If the surface of the sea was of the same temperature with the incumbent atmosphere, evaporation would cease whenever the hygrometric condition of the atmosphere reached the point of saturation, and no fog, unless a sinking of temperature occurred, would make its appearance. But the conse-

quence of the sea being warmer than the incumbent air, is, that evaporation continues to go on from its surface, after the atmosphere has become saturated, and, accordingly, when, without a rise of temperature, it can contain no more vapour in invisible solution. Hence an amount of moisture corresponding to what is evaporated after the air has become saturated, is condensed as it gets cooled by intermixture with the cold incumbent atmosphere, and gives birth to the description of fogs under consideration. Fogs produced in the manner above narrated, may be of any density, from the thinnest perceptible haze to the thickest mist.

Fogs on the coast of North America, and particularly along the course of the Gulph stream, are frequently produced in the manner above described. A cold atmosphere, transported by a north-west wind during winter, from the frigid latitudes of North America, comes sometimes to rest upon the then comparatively warm surface of the Atlantic ocean: and this inequality of temperature is further augmented, and therefore the more apt to occasion fogs, along the track by which the Gulph stream conveys an immense body of water from the equatorial towards the polar regions, which, when subjected to thermometric examination, is found to be several degrees warmer than other parts of the Atlantic, equally distant from the equator.

It may be remarked, that the formation of all fogs where the subjacent surface is warmer than the incumbent atmosphere, as is the case in the two preceding instances, is assisted by the sinking down, and

intermixture of the cold aerial strata above with those below, which have become relatively heated in consequence of their greater proximity to the warm surface underneath.

Fog sometimes makes its appearance at sea in opposite circumstances to those last mentioned, viz. when the atmosphere is warmer than the surface of the sea. This may occur when the wind subsides after blowing with force a day or two over a sea surface, from a warm towards a colder latitude; and more particularly, after blowing, during summer, from a southerly, heated, and, at the same time, damp land surface towards the ocean, and a colder latitude. If in either of these cases the superior coldness of the subjacent surface of the ocean be communicated to the incumbent atmosphere in sufficient intensity to produce oversaturation, fog begins to appear.

Another way in which a limited portion of the surface of the ocean is frequently rendered much colder than the incumbent atmosphere, is when large icebergs, frozen in some bay or inlet, are carried out to sea, and transported by winds, tides, and currents, to a warmer climate. The same thing also happens when great quantities of ice, frozen in some large river, such as the St Lawrence in North America, are carried by its current to the ocean upon the breaking up of the frost. In places and seasons of the year when icebergs are to be apprehended, such as near the coast of Newfoundland, during the latter half of spring, or beginning of summer, this species of fog, accompanied by a sudden, and otherwise inexplicable coldness, gives warning to the mariner, during night,

of his being in the vicinity of icebergs. In such cases, vessels, in order to avoid danger, generally *lie to*, and wait the return of daylight. This kind of fog, like the preceding, and analogously to all others, begins to present itself whenever the coldness of the subjacent ocean is communicated to the atmosphere in sufficient intensity to produce oversaturation.

Having thus given a detailed explanation of a variety of circumstances, in which a diminution of temperature, unaccompanied by atmospheric rarefaction, occasions a precipitation of moisture into the visible form of cloud or mist, we now proceed to consider those, in which the second mentioned cause of the formation of clouds, viz. *a diminution of atmospheric temperature arising from its rarefaction*, occurs.

The effect of a reduction of temperature occasioned by atmospheric rarefaction, in causing a precipitation of moisture into the visible form of cloud or mist, may be exhibited upon a small scale by means of an air-pump. If the air within the glass-receiver, attached to this machine, be suddenly rarefied, its temperature, as is exhibited by a delicate thermometer placed within the receiver, immediately sinks; and simultaneously with this reduction of temperature, a mist or haze within the receiver makes its appearance, which disappears again as the temperature rises, whether the rise be occasioned by the readmission of air, or by the passage of caloric by conduction through the glass, without the readmission of air. When the temperature within and without the receiver have become equal without the air being readmitted, its re-

admission causes the temperature within the receiver to rise above what it will continue to remain at.

The explanation of the phenomena, exhibited during the performance of the above experiment, is the following :—The sinking of temperature, exhibited by the thermometer within the receiver, as a portion of air is withdrawn, is owing to the calorific capacity of the remaining portion being increased by rarefaction. The circumstance of the temperature afterwards rising within the receiver to its previous elevation without any readmission of air, shows that a portion of the caloric within the receiver has been withdrawn along with the air ; and as caloric ceases to be withdrawn by suction when the air ceases to be farther rarefied thereby, it shows that the withdrawn caloric is attached to the air by affinity or attraction ; and that this abstraction of caloric has so far destroyed the calorific equilibrium, upon which equality of temperature depends, that caloric entirely separate from aerial particles, in obedience to the preponderance of calorific repulsion, is forced from without through the glass into the inside of the receiver, till the calorific equilibrium and equality of temperature is again restored. The rise of temperature within the receiver beyond what it will remain at, which takes place upon the readmission of air, after equality of temperature within and without the receiver has been established, also proves that a portion of caloric is firmly attached by attraction to the ponderable portion of aerial particles. Now, provided it be admitted, (and there is no reason for doubt upon this point,) that a part of the invisible aqueous vapour, proportioned to

the relative amounts of air and vapour previously within the receiver, is abstracted along with the air, it is obvious, that if the temperature within the receiver remained unaltered by the abstraction of a portion of air, instead of a part of the remaining aqueous vapour being thereupon condensed into the visible form of mist, the capacity of the diminished quantity of air remaining within the receiver for holding moisture in invisible solution, would be increased. Or again, if the capacity of air for moisture diminished in the same ratio as its temperature was lowered by rarefaction, and *vice versa*, increased in the same ratio as its temperature was raised by condensation, the abstraction of a portion of air could have no influence whatever in causing a precipitation of moisture, within the receiver, into the visible form of mist. In short, if such were the case, the dryness or dampness of the air, hygrometrically speaking, that is to say, its dryness or dampness relative to its capacity for moisture, would not be liable to alteration either by rarefaction or condensation. The true cause, therefore, of the appearance of mist within the receiver, as the air is suddenly rarefied by the process of exhaustion, results from the circumstance formerly stated, of the capacity of the air for moisture diminishing more rapidly than its temperature. While the temperature of air diminishes in arithmetical progression, its capacity for moisture diminishes in geometrical progression. Hence, supposing the air within the receiver to be exactly saturated with humidity, if its temperature be then lowered by rarefaction, a quantity of moisture proportioned to the difference of ratio in

which the aqueous capacity of air diminishes more rapidly than its temperature, would be precipitated into the visible form of mist.

A similar rarefaction of the atmosphere, and consequent reduction of its temperature and capacity for moisture, to what may be thus effected artificially, on a small scale, by means of an air-pump, is naturally produced on a large scale, when atmospheric currents, impelled by a preponderance of barometrical pressure, rise, while surmounting hills and elevated lands. The lower aerial strata as they ascend, expand by means of their elasticity, to a bulk proportionally greater, as the amount of air above them, and the pressure thereby produced diminishes. This expansion or rarefaction is accompanied by a proportional reduction of temperature. And this reduction of temperature produces, and is attended by a diminished capacity for moisture, proportioned, as before stated, to the difference of ratio in which the aqueous capacity of air diminishes more rapidly than its temperature.

Such is the arrangement of causes and effects by which atmospheric currents, in rising from a low level to surmount hills and elevated lands, have a tendency to become oversaturated with humidity, and thus to give birth to clouds. Of course, the altitude at which the temperature of the ascending current becomes so depressed by rarefaction that oversaturation commences, will mark the lower boundary where clouds begin to form. And this boundary will be lower or higher, according as the hygrometric condition of the atmospheric current, before beginning to ascend, is nearer to, or more distant from, the point of saturation.

The formation of clouds, according to the principles above described, is finely illustrated by the phenomena daily exhibited, during the dry season, over what are called the Liguanea, or Port-Royal mountains, in the island of Jamaica. These mountains are situated about four or five miles to the north-east by east of Kingston, the principal port in the island, and their height above the level of the sea is from four to five thousand feet. During the dry season, from the beginning of November till the middle of April, the sea and land breezes alternately succeed each other, with an intermediate interval of atmospheric stillness, in the following manner:—From sunrise till about 10 o'clock in the forenoon, it is usually perfectly calm. About 10 o'clock the sea breeze blowing at Kingston from the east, or rather a little to the south of east, commences, and continues till about half-past three in the afternoon, when it gradually and entirely subsides. The interval of atmospheric stillness which ensues lasts till a short time after sunset, when the land breeze begins, blowing from the central parts of the island in every direction towards the circumference, and, of course, at Kingston, blowing from the north-west. The land breeze continues all night, and till about sunrise, when it also gradually and entirely subsides; and then the same routine which we have now described, again commences, and it is repeated every day during the whole of the dry season.

About eleven o'clock every forenoon, or between that time and mid-day, the summits of the Port-Royal mountains begin to be covered with clouds; which, though thin, fleecy, and transparent at first, gradually

increase in density till about one o'clock. By this time, the upper portions of the mountains, when viewed from Kingston, seem to be wholly enveloped in dense clouds—rain is apparently falling in torrents—flashes of lightning are seen, and the sound of distant thunder is heard. About half-past two o'clock in the afternoon, the clouds, gradually diminishing in density, begin to quit the mountains, so that their summits again become visible as in the morning, and so continue till about eleven o'clock of the following day. The clouds, after quitting the mountains, rise gradually to a greater altitude, and float very slowly westward, assuming, as they proceed, the appearance of large heaped up *cumuli*. Such is a description of what occurs every day throughout the dry season, from the beginning of November till the middle of April. During the whole of this lengthened period, hardly a cloud is ever to be seen, except those formed over the distant mountains, during the continuance of the sea breeze, and which float slowly westward after quitting the mountains, as above described.

That the formation of the clouds, in the case above narrated, is the result of diminished temperature, and consequently of diminished capacity for moisture, as the atmospheric current becomes rarefied in its ascent over the mountains, is obvious from comparing the coincidences between the respective periods of time when the clouds begin to appear—reach their greatest density—and afterwards quit the mountains as their farther formation ceases; with those, when the sea breeze commences—attains its greatest velocity—and afterwards gradually and entirely subsides. The sea

breeze blowing from the south-east by east begins at Kingston about 10 o'clock, and the mountains (which, though only five miles distant from Kingston, are perhaps 12 or 15 from the sea in the direction of the sea breeze,) begin to be covered with clouds by 11 o'clock, or between that time and noon. Now, when it is considered, that the air resting upon the land intermediate between the sea and the Port-Royal mountains, must have become much heated, and therefore much undersaturated during the interval of atmospheric stillness before 10 o'clock, it is not at all likely that any degree of atmospheric oversaturation, and consequent formation of cloud, could take place, till the less undersaturated portion of air that had previously reclined over the sea during the interval of atmospheric stillness, had reached the summits of the mountains. And as the force of the sea breeze is at first small, and only increases, and extends itself inland by slow degrees; and as the less undersaturated portion of the atmosphere which had previously reclined over the sea, has 12 or 15 miles to travel over land, before reaching the mountains, the circumstance of an hour, or from that to two hours, elapsing after the sea breeze has commenced on the shore at Kingston, before the mountains become covered with clouds, is just what might be expected to happen.

Again, as the heat of the surface of the land, and of the atmosphere immediately incumbent, in warm climates, relative to that of the sea, and of the atmosphere thereupon incumbent, increases till about one o'clock in the afternoon, the velocity of the sea breeze which is produced and regulated by this difference of

temperature, increases also till about the same time; and afterwards gradually diminishes till about three o'clock, when it entirely subsides. Now the phenomena presented by the clouds over the Port-Royal mountains, are in exact accordance with what might be expected to result from this variation in the force of the sea breeze. When its velocity arrives at its diurnal maximum about one o'clock, a greater amount of air must undergo rarefaction, and consequent depression of temperature, and diminution in capacity for moisture, in its ascent over the mountains in a given time, than at any other period. And when this circumstance is considered along with the fact, that, according as the velocity of the breeze becomes greater, less time is allowed for the damp sea air to become heated and undersaturated before reaching the mountains, it is only what might be expected, that the clouds, owing to their more rapid and more copious formation, should then increase in density so much as to occasion torrents of rain; and that their density should again gradually diminish, and the rain cease, as the sea breeze subsides. Accordingly, about half-past two o'clock, when the sea breeze may be supposed to have so far subsided among the mountains, as to be no longer capable of forming clouds, and causing rain, the remaining clouds, as they become specifically lighter by the heat of the sun's rays, gradually rise above the mountain tops, and, moving slowly westward, assume the picturesque appearance of massy heaped up *cumuli*. These clouds, agreeably to the usual character of *cumuli*, descend, upon the approach, and during the early part of night, to a

lower altitude, and, breaking up into smaller pieces, slowly dissolve and disappear by evaporation. A cloudless sky thereafter ensues over the whole horizon, and continues till the usual period of the following day, when a similar nebulous creation makes its appearance, and which, after passing through a like course of existence, dissolves and evanishes in a similar manner.

Such is a description of the mode in which clouds are formed by the reduction of temperature, and consequently of aqueous capacity, which attends the rarefaction of atmospheric currents, while surmounting hills and elevated lands.

Mountains of themselves, that is to say, without wind, can form no clouds ; and winds of themselves, that is to say, without the aid of the atmospheric rarefaction which accompanies their exaltation while passing over mountains, are, in this respect, equally inefficient. Hence, over the Port-Royal mountains, before the sea breeze reaches them, the sky is as clear and unclouded as in any other part of the horizon. And, on the other hand, the sea breeze causes no formation of clouds immediately over Kingston, or over any other portion of the land where there are no mountains. In short, mountains in all climates may be regarded as passive instruments in the formation of clouds, only during windy weather. And whenever their height is such, that the temperature of the lower atmospheric strata, while surmounting them, becomes so much reduced as to cause oversaturation, the formation of clouds must take place. Hence, the higher the mountains, the more certain they are dur-

ing windy weather to cause the formation of clouds; and the nearer the hygrometric condition of the aerial strata, before beginning to ascend the mountains, is to the point of saturation, the less height will suffice for that purpose.

Accidental coldness on the tops of mountains, beyond what results from their height, sometimes adds to their efficacy in causing the formation of clouds. Such may be occasioned by snow-falls during the cold season remaining unmelted, or only partially melted, (as frequently happens on the northern exposure of mountains,) till long after the returning heat of spring and summer has rendered the falling of snow, at corresponding altitudes, extremely improbable.

When at Arrochar, about the end of April or beginning of May of the current year, (1834,) I had an opportunity of witnessing the influence of such accidental coldness in forming clouds. The mountains around this sequestered and romantic spot may vary in height from two to three thousand feet, and, at the time alluded to, patches, or possibly if more nearly inspected, fields of snow were to be seen on different parts of their rugged and fantastically shaped summits. The weather during the morning of observation was exceedingly fine and mild for the season of the year. Loch Long reposed in perfect stillness—not a breath of wind could be felt in the valley, and it could only be ascertained that the atmosphere above the mountains had a very slow progressive motion towards the east, by observing the change of position, which small fleecy clouds, here and there floating at an elevation similar to that of the mountains, underwent, when

viewed for sometime in relation to the mountain-tops. These fleecy clouds had probably been originally concentrated portions of mist which had formed, and rested during the previous night in hollows and places sheltered from the atmospheric progression, near the tops of mountains between Arrochar and the Atlantic, and which had been raised from their beds, but not entirely dissipated by the heat of the morning sun.

The circumstance that particularly attracted my attention, was the sudden increase in density, and the equally sudden expansion, to perhaps three or four times their previous bulk, which those small fleecy clouds underwent in the course of not more than a minute of time, when they touched upon the mountain-tops where I saw snow lying ; and also when they touched other localities, where, from the lowness of my place of observation, I could not see, but believed snow to be lying. These clouds, thus augmented in volume, instead of dissolving by evaporation with the advancing temperature of day, rose to a greater altitude while crossing Loch Long, and floating very slowly eastward, gradually congregated together, and assumed, as I watched them in my progress towards Helensburgh, in the course of the forenoon, the appearance of ranges of *cumuli*. This happened when over the whole horizon to the south, where the hills are less elevated, no cloud was to be seen.

Another circumstance that attracted my attention was, that I never could observe any formation of cloud taking place in any part of the atmosphere while progressing over the snow, except where a small cloud previously existed. The coldness, therefore, com-

municated by the snow, though sufficient for increasing the density and size of clouds previously formed, was not so great as to originate them, where none were before visible. Now, when it is considered, that at the time of observation, the force of the wind, as indicated by the extreme slowness with which the clouds were progressing, was so small as probably to be insufficient to communicate motion to the lower aerial strata, when obstructed by the rising acclivity of hills, it may be concluded, that the augmentation of bulk, which the clouds underwent upon approaching the vicinity of the snow, was entirely owing to the accidental coldness thereby communicated, and not at all produced by the ascent, and consequent rarefaction and reduction of the temperature of the lower aerial strata.

The circumstance also of no nebulous formation taking place in any part of the atmosphere while passing over the snow, except where some small cloud previously existed, showed that the air in the vicinity of those small fleecy clouds, was much nearer the point of saturation, than at a distance from them. Indeed, when it is considered that clouds consist of moisture in an intermediate state between invisible vapour and water, and that that moisture is favourably circumstanced for evaporation, from being not only surrounded, but completely intermixed with air, it might have been concluded, without observing the fact above stated, that the hygrometric condition of the atmosphere in the vicinity of all clouds, must be very near the point of saturation, for otherwise they would rapidly dissolve.

The case above narrated, together with that which preceded of the Port-Royal mountains in Jamaica, satisfactorily account for the great prevalence of clouds, not only immediately over the mountains where they are formed, but also for some distance to leeward. And as the formation of clouds is the constant forerunner of wet weather, they also account for the greater abundance of rain in mountainous districts, than in those of a champaign low lying character.

By way of illustrating this department of our subject a little farther, I shall here relate, and explain the phenomena which presented themselves on another occasion, which I had an opportunity of witnessing when residing one summer at Brodick-Bay, in the island of Arran. During the time I stopped there, I had twice previously ascended in clear weather to the top of Goatfell, which is the highest mountain in the island, and may be about 2900 feet in height. Being then young, my curiosity was not satisfied with the view from the top in clear weather, I wished also to see what could be seen when the mountain was enveloped in mist and clouds. Accordingly, one day when two-thirds of the mountain was shrouded in mist, and invisible from its base, I prevailed upon a stranger gentleman belonging to the navy to ascend along with me; and from my previous knowledge of the hill, I undertook, notwithstanding the mist, to direct our journey without the assistance of a guide. It was one of those calm days, when the whitish colour and hazy thick appearance of the air, when viewed perpendicularly upwards, indicated its being greatly over-

saturated with moisture; and when a very slight increase to the density of the aqueous vapour already precipitated and suspended in the atmosphere, would have caused it to descend in the form of drizzling rain. In our approach to the lower boundary of the mist, it was obvious that it descended to a much lower level over the mountain, than it did in the atmosphere at a distance from it. Except this, no meteorological phenomenon of importance presented itself till we reached the steep part, which may be called the cone of the mountain, and had advanced so far up it, as to be within perhaps about 300 feet of perpendicular height from the top. The mist hitherto had not been remarkable for its density, though in this respect it had very slowly increased from the time we entered within its limits. Its appearance was that of ordinary whitish coloured mist, floating in moderate density a few feet above the surface of the ground, and in rapidly diminishing thickness from that elevation downwards to the ground. During our farther ascent, however, the density of the mist increased with appalling rapidity; so much so, that at the summit of the mountain, it was greatly denser than any thing of the kind I ever witnessed; and instead of floating chiefly above our heads, and in diminishing quantity underneath, as it had previously done, it now extended to the ground in all its denseness. The ground was quite dry, and there was no visible deposition of moisture upon our clothes lower than about 300 feet perpendicular from the top. At this elevation, however, the ground assumed the appearance of dampness; and moisture, at first in such small quan-

tity as to be almost imperceptible, began to be deposited upon our clothes. In our farther ascent, this condition of the atmosphere gradually increased, so that, at the summit of the mountain, we found ourselves surrounded with an exceedingly dense mist, attended with drizzling rain. The gentleman who accompanied me being desirous of obtaining a view from the top, and having no other opportunity of ascending, as he purposed to leave the island the following morning, it was agreed that we should remain twenty minutes, to see if the mist would clear away. In the meantime, to shelter ourselves from the drizzling rain, we crept under a granite rock projecting from the brow of the hill. Having waited the length of time agreed upon, without the mist showing any signs of disappearing, or the rain of abating, we commenced our descent; and the same phenomena we had seen in ascending, in reversed order again presented themselves. The mist rapidly decreased in density; and when we got beyond about 300 feet of perpendicular descent from the top, the rain ceased, and the ground appeared perfectly dry. I conceive it therefore presumable, that though there was no rain at a lower level than about 300 feet perpendicular from the summit of the mountain, it rained above that elevation, the quantity increasing towards the top, in a drizzling form during the whole day.

Such were the meteorological phenomena which presented themselves; and these we shall now endeavour to explain.

The first circumstance requiring consideration, is the descent of the mist to a lower level over the

mountain than it did in the surrounding atmosphere free of the mountain. Provided the force of the wind had been considerable, I should have supposed that the descent of the mist was more apparent than real; and that it was owing principally to the circumstance of additions being made to its lower portion, by the rarefaction of the lower aerial strata while ascending the mountain. But as the atmosphere at the time was so near a state of perfect stillness, that it could with difficulty be determined in which direction it was moving, I am disposed to attribute the descent of the mist in this case, chiefly to an attractive force which mountains usually exert upon clouds and mist, so as visibly to draw them downwards, and, in some degree, to arrest, or retard their progress while passing over them. Such attractive influence may arise in various ways, such as, from clouds being over or undercharged with electricity relative to the subjacent earth. It is certain that clouds, on some occasions, are actuated by one or other of these relative electrical conditions, and, in my opinion, such occurs more frequently than is generally supposed. It may arise also from the subjacent earth exerting a stronger attractive influence upon the precipitated aqueous vapours composing clouds, than upon the gaseous elements which compose the atmosphere; and this may be occasioned by the former being more apt to acquire by induction, a different electrical state from the subjacent earth, or that different state in a stronger degree, than the latter.

To the preceding opinion it may be objected, that if mountains attract clouds and mist downwards, the density of the mist, agreeably to the law of distance,

should have increased as it approached the surface of the ground; whereas, before reaching the cone of the mountain, though the mist appeared to float in considerable density a few feet above the surface of the ground, its density, instead of increasing, rapidly diminished from that elevation to the ground.

The explanation of this seeming contradiction to the hypothesis of mountains attracting clouds, is the following:—The preceding portion of the summer had been remarkable for heat and dryness; and, as always happens in such circumstances, the ground, at and near its surface, must have acquired a higher temperature than the atmosphere. According therefore to the principle of caloric being always directed in its movements by the preponderance of calorific repulsion, it follows, that the surface of the ground must have been gradually imparting a portion of its previously absorbed caloric to the air, and this more particularly, as the higher atmospheric strata were at that time so loaded with precipitated aqueous vapours, as to be altogether impervious to the calorific rays of the sun. The mist, therefore, which we have supposed to have been attracted downwards by the mountain to a lower level than its specific gravity would have otherwise determined, and possibly also in some slight degree formed by its influence in elevating, and thereby depressing the temperature of the slow-moving atmospheric current, was partially dissolved, and reconverted into the invisible state, and also rendered specifically lighter by the heat which was gradually emanating from the ground. Owing, however, to the great increase in the density of the mist, and the

cooling effect of the moisture deposited upon the ground at and near the summit of the mountain, the previously absorbed caloric, by the time we ascended, was probably emanating from the ground in such small quantity, (if at all,) as to be incapable of dissolving any appreciable proportion of it. And, consequently, the mist there appeared to extend in undiminished density to the surface of the ground.

The most remarkable fact, however, was the quantity of drizzling rain that was falling at the summit of the mountain, when within such a short distance, as about 300 feet of perpendicular height down the steep sides of its cone, it was perfectly dry. It is obvious that had the mist been as dense, and its particles as large and heavy, at an equal elevation in the surrounding atmosphere clear of the cone of the mountain, as they were immediately over it, drizzling rain, contrary to what we experienced, must have been falling upon us during our whole ascent. Now, when it is considered that the drizzling rain was limited to the upper part of the cone of the hill, which, from its height, may be supposed to have reached those atmospheric strata where the mist was floating in greatest density; and, when it is farther considered, that the air may have been progressing at the rate of a mile or two in the hour, (a thing which happens, as is evident by observing smoke, in almost the calmest weather we ever have in this country,) it is probable, that the increase in the density of the mist, and the running together of its particles into drops, so as to give rise to drizzling rain, was partly occasioned by the attractive influence of the mountain in concentrating the mist

near its summit, and partly also by the interruption, exaltation, and intermixture, of conflicting atmospheric currents, while surmounting the cone of the hill.

The case above narrated and explained affords an illustration, though not a good one, of the influence of mountains in robbing the aerial current of a portion of its moisture. Owing to the extremely limited extent of the summit of Goatfell, its influence in this respect must have been very inconsiderable. But supposing that a lengthened mountain range of equal elevation, (and the greater its height the more powerful its influence,) had extended transverse to the atmospheric current, it is obvious, that the air to leeward must have contained less moisture than it did to windward, in proportion to the quantity deposited upon the mountains, and returned to the sea by rivers. It is upon this principle that the want of rain in the kingdom of Peru, lying to the west of the Andes, (as well as all similar cases,) is usually accounted for. The trade-wind, which in that region blows uniformly from the east, is robbed of a large proportion of its moisture while passing over this elevated range of mountains. And the moisture so precipitated, originates, and is returned to its parent source by those immense rivers which traverse the South American continent, from the Andes eastward to the Atlantic ocean.

Another way in which the atmospheric temperature may be reduced by aerial rarefaction, though probably of little efficacy in the formation of clouds, is where the amount of atmosphere over any place becomes less, and which is indicated by a sinking of the barometer.

Such may occur when the atmospheric temperature, on the continent of Europe, sinks rapidly upon the approach of winter, below what it is in this island. In that case the first effect is, that a portion of the upper half of the atmosphere floats over upon the cold and depressed air of the continent. And this, until re-action is produced in the lower half of the atmosphere, should occasion a sinking of the barometer in this country, and a rarefaction of the aerial strata, which will be greater the more elevated, and the nearer they are to those which have been withdrawn. On the other hand, an increase in the amount of air vertical to any place, and which is indicated by a rise in the barometer, may slightly assist in accelerating the dissolution of clouds, by means of the aerial condensation and evolution of heat which it occasions. Such may probably be one reason, though not the most important, why a sinking of the barometer is an indication of wet weather; and why a rise in that instrument prognosticates dryness.

Another way in which the diminution of atmospheric temperature arising from atmospheric rarefaction takes place, is when cold currents of air, in consequence of their greater specific gravity, insinuate themselves underneath, and gradually uplift warmer atmospheric strata to a colder altitude. In the next chapter we will endeavour to show that what is called the rainy season in intertropical climates, is partly, if not principally produced in this manner.

But the great bulk of clouds in temperate and cold climates are formed independently of aerial rarefaction produced by mountains, for they frequently originate

where none are to be found, such as at sea, and when no aerial rarefaction occurs. They likewise are formed in circumstances totally different from those in which fogs and mist make their appearance; for instead of originating in, and being restricted to, the portion of the air nearest the ground, they are formed and float only in high regions of the atmosphere. This brings us to the consideration of the third cause of the formation of clouds, *viz. when a diminution of the atmospheric temperature, arising from the transportation of air from a warm to a cold climate, by the agency of winds, takes place.*

When treating, in the first chapter, of the causes which produced an undersaturated state of the atmosphere with regard to humidity, the influence of a wind blowing from a warm towards a cold climate in producing clouds, and causing rain, was fully explained. As this, however, appears to be the principal cause of the formation of clouds, at least in all temperate and cold latitudes, we may recapitulate the substance of what was formerly stated.

When the wind blows from a southerly direction in the northern hemisphere, or from a northerly direction in the southern hemisphere, air is thereby transported from a warm to a comparatively cold climate. And as it cools in advancing towards colder latitudes, its capacity for moisture gradually diminishes. Hence, though previously undersaturated with humidity, it gradually approaches the point of saturation, and at length oversaturation, and the formation of clouds commences. And when the clouds, in the progress of formation, acquire the requisite degree of density, rain ensues.

On the other hand, when the wind blows from a northerly direction in the northern hemisphere, or from a southerly direction in the southern hemisphere, air is thereby transported from a cold towards a comparatively warm climate; and, as it becomes warmer in advancing towards a warmer latitude, its capacity for moisture gradually increases. Hence, though previously saturated with humidity, it gradually becomes more or less undersaturated; and clouds previously formed slowly dissolve by evaporation, and dry weather, and a cloudless sky, is the consequence.

These observations explain the reason why southerly winds in the northern hemisphere, and northerly winds in the southern hemisphere, are more prolific of clouds and wet weather than winds from the opposite direction. It may be added, however, that when the wind, in its progress from a warm towards a cold climate, has crossed mountain ranges, or other elevated lands immediately previous; and also when it has just passed over an extensive tract of dry and heated land, it may have become so much undersaturated thereby, that for a considerable distance to leeward, any reduction of temperature which it undergoes, may be insufficient, or perhaps little more than sufficient, to bring up its hygrometric condition to the point of saturation. In the former circumstances no clouds can be formed; in the latter, their formation may not be sufficiently copious to produce rain.

Again, when the wind blows from the ocean towards the land during winter, when the surface of the former is much warmer than that of the latter; and also when it blows from the land towards the ocean during sum-

mer, when the land is much warmer than the ocean, the circumstances and the explanation are analogous to the instance already given of the wind blowing from a warm towards a cold climate. In such cases, the atmosphere as it becomes colder has its capacity for moisture diminished. Hence, though previously undersaturated, it gradually approaches the point of saturation. And so soon as oversaturation begins to be thereby effected, the formation of clouds commences. Of course, in the case of the wind blowing from the ocean towards the land during winter, the formation of clouds and wet weather takes place over the land; whereas, in the case of the wind blowing from the land towards the ocean during summer, the formation of clouds and wet weather occurs at sea. It requires, however, to be noticed, that the wind from the ocean is much more likely, in the above circumstances, to produce clouds and wet weather on shore, than the wind from the land is to occasion clouds and wet weather at sea. The reason of this difference is, that wind blowing from the ocean is always either saturated, or nearly saturated, with moisture, and therefore apt to give birth to clouds and rain, when the slightest reduction of temperature takes place. Whereas, wind blowing from the land is frequently so much undersaturated, that all the reduction of temperature which it undergoes, may not be sufficient to bring up its hygrometric condition to the point of saturation, and, of course, no clouds, in such circumstances, can be formed.

In the reverse circumstances to those above explained, viz. when the wind blows from the ocean

towards the land in summer, especially during its latter half, when the heat of the land relatively to that of the sea is greatest; and also when it blows from the land towards the ocean, during the coldest period of winter, the circumstances and the explanation are analogous to the other previously given instance, of a wind blowing from a cold towards a warm climate. In such cases the atmosphere, as it becomes warmer, has its capacity for moisture increased. Hence, though previously saturated with humidity, it gradually becomes more or less undersaturated, and clouds previously formed gradually evaporate and disappear. The former of the winds above mentioned is therefore favourable to fair weather on shore; and the latter is still more favourable to fair and cloudless weather at sea.

In our insular situation, surrounded by, and at no great distance from, the ocean in any direction, the truth of the preceding remarks is not so apparent. But on continental shores, such as the United States of America, and other similar localities, the explanations thereby afforded of the different kinds of weather, which, during the specified seasons, accompany certain winds, demonstrate their accuracy.

At Marseilles, situated in the south of France, and on the coast of the Mediterranean, in north latitude 43° 18′, the truth of the principles which we have endeavoured to explain in the preceding pages, is strikingly illustrated. During winter, and early in spring, (and it is only to these periods of the year that our immediate remarks apply,) the most frequent changes in the direction of the wind are from north to south, and the reverse, viz. from south to north;

The most prevalent direction, however, is from the north. The wind from this direction, during the season of the year above mentioned, is denominated the Mistral. It continues generally for three successive days at a time, its velocity being usually considerable, and sometimes great, especially on the third day. During the continuance of this wind, neither a cloud nor the slightest haze can be seen. The colour of the sky is dark blue, which indicates that the air is extremely undersaturated with humidity, and that the aqueous vapour therein contained is thoroughly dissolved. This wind is so remarkable for dryness, and its power of absorbing humidity from all moist surfaces so great, that plants and vegetables of every kind have their juices extracted by it to such an extent, that during the cold season, when the severity of a northerly wind there is only felt, they present a stunted and withered appearance, greatly beyond anything ever seen in this country; and, like our north-east wind in spring, which it resembles, but much surpasses in refrigerating influence, it is extremely piercing and cold.—We shall now explain the causes of these phenomena.

The absence of every thing like haze, or cloud, during the continuance of this wind, as well as the characteristic dryness of the atmosphere, and the other peculiarities therefrom resulting, are owing to the conjoint influence of the following very favourable combination of circumstances :—1. This wind blows with considerable, and sometimes great velocity, in the direct course from a cold towards a warm climate, viz. from north to south, over the central districts of

France, which, during winter, experience a degree of cold seldom or never felt in this island. Hence, agreeably to the principles we have been explaining, as the atmosphere is gradually becoming warmer, and its capacity for moisture increasing, it is simultaneously becoming more or less undersaturated; and consequently no formation of clouds, during its continuance, can take place. 2. It blows from the land towards the sea, during the season of the year, (viz. winter,) when the surface of the former is much colder than that of the latter. This circumstance, by contributing to render the transition from a cold to a comparatively warm climate greater, and more sudden, adds to the influence of the one above-mentioned, in increasing the hygrometric dryness of the aerial current as it approaches the Mediterranean coast, upon which Marseilles is situated. 3. It blows over from 500 to 600 miles of dry land, and in its passage crosses ranges of elevated mountains. The combined influence of these and the preceding circumstances, which are all separately favourable to dryness, produces an extremely undersaturated state of the atmosphere with regard to humidity. Hence, whatever clouds or haze may have existed before the wind shifted to this direction, are rapidly dissolved by it. And as no clouds can be formed during its continuance for the reasons above-mentioned, neither cloud nor haze are visible.

On the other hand, when the wind, after blowing for some time from the north, suddenly changes, and blows from the south, that is, from the Mediterranean, the combination of circumstances are reversed. And

being now as favourable for producing an oversaturated state of the atmosphere with regard to humidity, and a clouded sky, as they previously were for producing the opposite condition, the formation of the clouds, aided also by the rising grounds in the neighbourhood of Marseilles, rapidly goes on ; and rainy weather soon follows. But whenever the wind again shifts from the south to the north, and the Mistral begins to blow, the rain ceases, and the clouds dissolve and disappear with astonishing rapidity.

We now come to treat of the fourth cause of the formation of clouds, *viz. When an intermixture, and consequent reduction to a mean temperature, of different portions of air, of previously different temperatures, takes place.*

It having been revealed by Saussure's experiments, that while the temperature of air increases in arithmetical progression, its capacity for moisture advances in geometrical progression, Dr Hutton was led to account for rain upon the principle, that, if different portions of atmosphere, previously saturated with humidity, and of different temperatures, were intermixed, a precipitation of moisture must take place. This mode of accounting for the precipitation of humidity from the atmosphere has been denominated, from the name of its author, the Huttonian theory of rain. But, as the precipitation of moisture into the visible form of mist or clouds, is not always attended, or even followed by the falling of rain, (for clouds, after being formed, frequently again evaporate without producing rain,) and as there never is rain without clouds, it might, with more propriety, have been denominated

the Huttonian theory of clouds. We shall here endeavour fully, and precisely, to explain its principles.

It has been already stated that the capacity of the air for humidity, when reduced to a mean rate, doubles itself for every increment of temperature amounting to 23.4 degrees.* Accordingly, if the capacity of the air at the temperature of 23.4 be denominated 2; its capacity, at the temperature of 46.8, must be denominated 4; and at the temperature of 70.2, must be 8. Now, supposing two equal portions of air previously saturated with moisture, the temperature of the one being 23.4, and that of the other 70.2, to be intermixed, so as to produce a mean of 46.8. It is obvious, by comparing the separate capacities of the two portions of air at their respective temperatures, with the capacity of both reduced to a mean temperature, that intermixture must produce a precipitation of humidity. Thus, the number denoting the aqueous capacity of the air at the mean temperature of 46.8 is 4; but the mean capacity of the air for the two extreme temperatures, denoted respectively by the numbers 2 and 8, is 5. Hence, it appears, that $\frac{1}{5}$th of the whole aqueous vapour which the two supposed portions of atmosphere are capable of dissolving when separate, would be precipitated upon their acquiring a mean temperature by intermixture.

For the sake of avoiding confusion, the above calculation makes no allowance for the deduction which would have to be made for the evolution of heat,

* According to Leslie, the capacity of the air for moisture, when reduced to a mean rate, doubles itself for every increment of temperature, amounting to 27 degrees.

which accompanies the conversion of invisible into visible vapour. If the atmosphere was previously so much undersaturated, that the intermixture of two equal portions of different temperatures did not produce any precipitation of humidity, their intermixture would necessarily reduce them to a mean temperature. But as heat is always evolved when any conversion of moisture from the invisible to the visible state takes place, the result of intermixture, when precipitation occurs, will be a temperature more or less above the mean, according to the amount of moisture precipitated. And as the capacity of air for dissolving humidity increases with its temperature, according to the previously stated ratio, it is obvious, that the proportion of moisture precipitated, upon the intermixture of different portions of saturated air of different temperatures, must be somewhat less than the principle adopted in the preceding calculation gives.

Now, as analogous results to those above stated, are produced by every intermixture of atmospheric strata of different temperatures, it follows, that if the different strata be saturated with humidity when separate, intermixture must always produce precipitation; and if they be undersaturated when separate, intermixture, if it fall short of producing precipitation, will, at all events, bring them nearer the point of saturation.

But though the principle, according to which clouds may be formed, by the intermixture of different portions of air of different temperatures, has been discovered, the circumstances in which such inter-

mixture takes place in nature, has never, so far as my very limited reading goes, been pointed out. Upon this point Dr Prout * says, "Clouds probably depend altogether on *convection ;* and result from the intermixture of strata of air of different temperatures, and in different states of saturation, in the higher regions of the atmosphere.

"Such," continues Dr Prout, "is the general opinion of the formation of clouds; but it must be confessed that there are considerable difficulties about the subject ; and that the mere assumption of strata of different temperatures, more or less saturated with vapour, and having the motions supposed to depend upon such different temperatures and degrees of saturation, seems quite inadequate to account for all the phenomena connected with the formation and appearance of clouds."

In what follows, I will endeavour to point out, and explain, the circumstances in which intermixture of different portions of air of different temperatures takes place, so as to occasion the formation of clouds, according to the Huttonian principle.

In order to understand the circumstances above alluded to, let it be recollected, that the temperature of the atmosphere diminishes at the mean rate of one degree of Fahrenheit for every 300 feet of perpendicular ascent ; and that this, as explained by Leslie, results from the capacity of air for heat being increased in exact proportion as it becomes rarefied by the diminution of atmospheric pressure. This explana-

* Bridgewater Treatise, p. 316.

tion, we casually remarked while commenting upon it, might be applied to explain the otherwise inexplicable fact, of the cold air in the higher atmospheric regions, having no tendency to change places with the warm air below, so long as the mean rate of decrement was preserved. That this application is correct, is obvious from considering, that, in an atmospheric column extending perpendicularly upwards from the ground, the diminution of temperature which each molecule manifests, according as it is higher up the column, results not from its having less heat attached to it, but from that heat being expanded over a proportionally larger space. The colder molecules above are therefore absolutely of the same weight, and specifically also, except for the difference arising from the different degrees of force by which they are compressed at different altitudes, with the warmer ones below, and consequently can have no tendency to displace them.

Now, the only circumstance in which an intermixture of different portions of the atmosphere of different temperatures takes place, *is when the upper molecules of air have severally a smaller amount of heat attached to them, and consequently, after making allowance for the rarefaction arising from the diminution of atmospheric compression as their position becomes more elevated, are specifically heavier than those below.*

Admitting then, (though this point possibly requires re-examination,) that the decrement of one degree of Fahrenheit for every 300 feet of perpendicular ascent, is the exact ratio at which every particle or

stratum of air is at every elevation, specifically of the same weight, except for the difference resulting from its being less compressed, according as its position is more elevated, intermixture must take place at any altitude, where the ratio in which the decrement of the atmospheric temperature exceeds one degree of Fahrenheit for every 300 feet of perpendicular ascent. And the more it exceeds this ratio, the greater will be the tendency of the upper strata to sink down, and intermix with those below. On the other hand, at whatever altitude the ratio in which the decrement of atmospheric temperature is less than one degree of Fahrenheit for every 300 feet of ascent, the upper and lower particles will be more unfavourably circumstanced for intermixing, than when the temperature decreases at the mean rate of one degree for every 300 feet of ascent. The reason of this is, that in the former case, viz. when the temperature decreases at a less ratio than one degree for every 300 feet of ascent,—the lower aerial particles are colder, and consequently specifically heavier than those above, after the necessary allowance is made for the greater atmospheric compression to which they are subjected. Whereas, in the latter case, after the necessary rectification arising from difference of compression is made, (and which, in what follows, is always to be understood without being again mentioned,) the upper and lower aerial particles are precisely of the same temperature, and the same specific gravity.

Provided the commonly received opinion, that the upper half of the atmosphere moves in an opposite direction from the lower, was in all cases correct, a

sinking down and intermixture of the upper with the lower half of the atmosphere would take place, whenever the wind in the lower half blew from a warm towards a comparatively cold climate. In this case, a warmer and lighter atmosphere would be brought underneath a colder and heavier one. For instance, if the direction of the wind in the lower half of the atmosphere be from the equatorial towards the polar regions, while that of the upper half is from the polar towards the equatorial; the former will be transporting the heated air of a warm to a cold climate, while the latter is transporting the cold air of a cold, to a warm climate. The consequence of this will be, that the decrement of temperature at the plane where the two currents meet, will be much greater than the rate of one degree for 300 feet of ascent. Hence, the aerial particles of the upper current will be colder, and therefore specifically heavier than those of the lower current; and consequently, will sink down and intermix with them. Now, provided the upper and lower currents of air be saturated with humidity when separate, the precipitation of moisture into the visible form of cloud will begin so soon as intermixture commences. And if they be undersaturated when separate, intermixture, if it fall short of producing precipitation, will, at all events, bring them nearer the point of saturation. Of course, the sinking down and intermixture of the upper half of the atmosphere with the lower, and the consequent formation of cloud, supposing the atmosphere previously saturated with humidity, will go on with greater rapidity, according as the coldness and gravity of the undermost strata of

the upper half, exceed those of the uppermost strata of the lower half. And as the sinking down, and intermixture of the upper aerial particles with the lower, is a slow and gradual process, it may be added, that if one or both currents be previously somewhat undersaturated, but not to the extent required to prevent their intermixture and reduction to a mean temperature, producing a state of oversaturation, the formation of cloud will commence earlier after intermixture has begun, according as both currents, (and particularly the lower, as its aqueous capacity is greatest,) are previously nearer the point of saturation.

On the contrary, if the direction of the wind in the lower half of the atmosphere be from the polar towards the equatorial regions, that is, from a cold towards a warm climate, while that of the upper half is from the equatorial towards the polar, the former will be transporting the cold air of a cold to a warm climate, while the latter is transporting the warm air of a warm to a cold climate. The consequence of this will be, that at the plane where the two currents meet, the decrement of temperature will be less than the rate of one degree for 300 feet of ascent. Hence, the aerial particles of the upper current will be warmer and specifically lighter than those of the lower; and consequently, no sinking down nor intermixture of the former with the latter, nor formation of clouds dependent upon intermixture, can take place.

Provided it could be demonstrated that the commonly received opinion upon this point is correct, viz. that the upper half of the atmosphere always moves in the opposite direction from the lower, it is obvious,

that the intermixture of atmospheric strata of different temperatures would occur in the circumstances above explained; and that the formation of clouds, as exemplified in nature, would harmonize therewith. That the upper half of the atmosphere moves in the opposite direction to the lower, in the case of sea and land breezes, monsoons, and generally, when the prevailing direction of the wind in the lower half of the atmosphere is from a cold towards a warm climate, (especially if the increment in the aerial temperature within a moderate distance horizontally be considerable,) can hardly be doubted. In such cases the atmosphere in the warm climate, by being expanded upwards, in consequence of superior temperature to a greater elevation than that in the colder climate, generates a current in the upper half of the atmosphere from the former towards the latter. But while this current diminishes the atmospheric pressure over the warm district, by withdrawing a portion of air from the upper extremity of the atmospheric columns thereupon incumbent, it simultaneously supplies air to the atmospheric columns, and consequently, increases the atmospheric pressure over the cold district. Hence, a counter-current in the lower half of the atmosphere, from the cold towards the warm climate, is generated and maintained.

The preceding principle of accounting for the simultaneous existence of two opposite atmospheric currents, cannot be applied to any case where the direction of the wind in the lower half of the atmosphere is from a warm towards a cold climate, as is exemplified during winter by a west or south-west

wind blowing from the Atlantic towards Britain, and the western shores of Europe. In such circumstances, to suppose that an opposite current simultaneously blows in the upper half of the atmosphere from a cold towards a warm climate, would be reversing the principle which determines the prevailing direction of the wind. The proximate cause of wind is a difference in the incumbent atmospheric pressure in different places, at a similar elevation in reference to the level of the sea. And the direction of the wind at all similar altitudes above the level of the sea, is always from where the incumbent atmospheric pressure, or in other words, from where the incumbent amount of air, (that is, the amount of air above the altitude of observation,) is greater, to where it is less. But even though the amount of atmosphere were the same over the cold as over the warm climate, the atmospheric columns, in consequence of being colder, would be less elevated over the former than over the latter. Hence, it is impossible, according to dynamical principles, that a current in the upper half of the atmosphere from the cold to the warm climate can exist, while the wind near the earth's surface is blowing in the opposite direction.

Now, the rainy direction of the wind in all latitudes beyond the tropics, is when it blows in the lower half of the atmosphere from a warm towards a comparatively cold climate. But we have above demonstrated, that in such circumstances no opposite current in the upper half of the atmosphere can exist. Hence, the intermixture of aerial strata of different temperatures, by which the formation of clouds might be ex-

plained, cannot result from the opposite direction of the wind in the upper and lower halves of the atmosphere, bringing a colder and heavier air to rest over a warmer and lighter one.

When we come to treat of irregular winds, we will endeavour to show that the prevailing south-west wind in Britain, and along the western shores of Europe, is owing to the mean atmospheric pressure being greater over the Atlantic lying to the south-west, than over Britain and the western parts of Europe. And this, we conceive, is produced partly by the augmentation which the atmosphere over the Atlantic, in the direction of the Gulf of Mexico, is continually receiving in the form of aqueous vapour, supplied from the watery surface underneath, and partly by the diminution which the atmosphere, in its north-east progress toward a colder climate, sustains, by the descent of a large proportion of that aqueous vapour in the form of rain.

Supposing it granted, that the west and south-west, which are the rainy winds in Britain, and in the western countries of Europe, are owing to the causes above mentioned; I am disposed to think, that the whole atmosphere, from the earth upwards to its summit, must generally move in the same direction, not only in this case, but in all others, when the wind blows from a warm towards a comparatively cold climate. At the same time, as air becomes denser in the ratio of compression, I infer, that in such cases, the force which produces wind, viz. the superiority of atmospheric pressure in one place over another, at an equal altitude above the level of the sea, increases as we

approach the surface of the earth. Consequently, except for the counteractive resistance of friction on the surface of the earth, and which must be propagated upwards with diminishing effect from one aerial stratum to another, that the velocity of the wind also increases the nearer we descend in the atmosphere to the earth's surface. For these reasons, together with the fact of moisture being abstracted in the form of rain, only from the aerial strata within a limited distance of the earth's surface, I am inclined to think, that the greatest velocity of the atmospheric current is, in most cases, restricted to within a mile, or perhaps two, of the level of the sea; and that above some such altitude, its velocity gradually decreases. This opinion is somewhat confirmed by the great velocity with which clouds, suspended at a low altitude, apparently move, when compared with those at a greater elevation, even after allowance is made (estimated, however, merely by ocular observation,) for the optical illusion produced by the greater distance of the latter.

Now, upon the supposition that the velocity of a wind blowing from a warm towards a cold climate, begins to diminish at the elevation of 5000 or 6000 feet above the level of the sea, the air underneath this altitude, in consequence of having been transported from a more southern climate, should be warmer, and specifically lighter, than that which moves with diminished velocity above. Hence, the sinking down and intermixture of the superior with the inferior strata, and the consequent formation of clouds, may be going on at that moderate degree of elevation. And upon

the supposition that the velocity of the atmospheric current gradually diminishes on ascending perpendicularly above the altitude of 5000 or 6000 feet, each atmospheric stratum should be warmer than that immediately above it, for the same reason, viz. its having been transported, in the same time, from a more southerly, and therefore a warmer climate. Consequently, the sinking down and intermixture of the superior with the inferior strata, should be going on in such circumstances, not only at the elevation of 5000 or 6000 feet, but for a great distance above.

On the other hand, when the wind blows from a cold towards a warm climate, provided its velocity gradually diminishes upon ascending above the elevation of 5000 or 6000 feet, the inferior atmospheric strata, in consequence of having been transported a greater distance in the same time, should be colder and heavier than those above. Hence, in this case, the superior atmospheric strata should have no tendency to sink down and intermix with those below them, and consequently, no formation of clouds, arising from the intermixture of aerial strata of different temperatures, can in such circumstances occur.

Provided the commonly received notion, that the upper half of the atmosphere moves in the opposite direction of the lower half, had been correct; when the latter blows from a warm climate, the intermixture of atmospheric strata of different temperatures, according to the principles previously explained, would have been an exceedingly prolific cause of the formation of clouds. But upon the principle which we have advanced, that when the wind blows from a warm towards

a cold climate, the whole atmosphere moves in the same direction, with merely a gradual diminution in its velocity above the altitude of 5000 or 6000 feet, (and this conclusion itself requires to be re-examined,) the intermixture of atmospheric strata of different temperatures, may be regarded as exerting an inferior influence in the formation of clouds, and one which is merely auxiliary to the third cause of their formation, viz. the reduction of temperature which attends the transportation of air from a warm to a cold climate, by means of atmospheric currents.

Another case in which intermixture of atmospheric strata of different temperatures should take place, is *when a greater degree of heat is communicated to aerial strata at any given altitude, than what is imparted to those above them.* Thus Humboldt found, that the rate in which the temperature of the atmosphere diminished upon ascending perpendicularly, became less in the region of the atmosphere where clouds are formed, than what it was either below or above. This he ascribed to heat evolved during the conversion of invisible vapour into clouds. Supposing, therefore, that clouds are forming in the atmosphere, in consequence of the transportation of air from a warm to a cold climate, the evolved heat must raise the temperature, and diminish the specific gravity of the atmospheric strata, where their formation is taking place. Consequently, the aerial strata immediately above, which have not participated in this accidental accession of warmth, must begin to sink down and intermix with them. And this intermixture must necessarily assist in increasing, and in some degree

perpetuating, the formation of clouds. But it is not only at their formation that clouds communicate additional warmth to the adjoining atmospheric strata; they are also subsequently indirect agents in raising the temperature of the atmosphere in their immediate neighbourhood. Thus they partially arrest the solar heat in its progress to the earth during day, and in its retrocession by radiation from the earth during night. The heat so arrested may be spent partly, perhaps, in dissolving the clouds; but it must also be partly communicated by conduction to the neighbouring atmosphere. This augmentation of temperature, by diminishing the specific gravity of the atmospheric strata in which the clouds float, causes those above, which have not participated in this accidental accession of warmth, to sink down and intermix with them, and thus to assist in their formation.

Hence we see that the existence of clouds in the atmosphere exerts an influence in promoting their farther formation. Not only the heat evolved during their formation, but that which is subsequently arrested by them, tends to increase, in their immediate neighbourhood, the mean rate at which the temperature of the atmosphere upon ascending perpendicularly diminishes. And this, agreeably to the principles already explained, occasions a sinking down and intermixture of the superior atmospheric strata with those immediately below; and, provided the intermixing strata be previously saturated with humidity, must produce an additional formation of clouds.

As the solar heat accumulates at the earth's surface without imparting almost any additional warmth

to the atmosphere through which it radiates, the augmentation of temperature which the air undergoes during day, is chiefly communicated upwards from the earth's surface. Owing to this circumstance the accession of warmth which the different atmospheric strata acquire during day, diminishes upon ascending perpendicularly from the earth's surface. Hence, agreeably to the principle of the equilibrium of the atmospheric strata being disturbed, whenever the decrement of temperature upon ascending perpendicularly exceeds one degree for every 300 feet, a sinking down and intermixture of the superior with the inferior strata, must, in such circumstances, take place. But, as the augmentation of temperature above alluded to, is almost always spent (at least over dry land, where it is greatest,) in producing an under-saturated state of the atmosphere with regard to humidity, the sinking down and intermixture of the strata referred to above, has seldom or never any influence in producing clouds.

The preceding observations sufficiently explain the principles upon which the formation of clouds, resulting from the intermixture of saturated, or nearly saturated atmospheric strata of different temperatures depend, and the circumstances in which it occurs. It is therefore unnecessary further to enlarge upon this point.

Since the promulgation of the Huttonian theory of rain, it has been generally believed by meteorologists, that the formation of clouds in the higher regions of the atmosphere, is principally owing to the cause which we have been last considering, viz., the inter-

mixture of atmospheric strata of different temperatures. But, after having reviewed all the more important circumstances in which intermixture of atmospheric strata of different temperatures can reasonably be supposed to occur, and which is altogether omitted by other meteorological writers, I am inclined to think, that this fourth cause has much less influence in the formation of clouds, than the one previously treated of, viz., when a diminution of the atmospheric temperature, arising from the transportation of air from a warm to a comparatively cold climate by the agency of winds, takes place. It is obvious, however, that the cause of the formation of clouds last treated of, must always co-operate less or more with the two considered immediately previous. And, owing to this circumstance, it is difficult to appreciate their separate influence.

We have now, at considerable length, explained the causes and principles which determine the formation of clouds. It is evident, upon reviewing the subject, that, with the exception of some of the circumstances enumerated under the first cause of the existence of clouds, wind is a necessary agent in their formation. If there was no such thing as wind, which would be the case if the air was not liable to expansion by means of heat, no clouds, with the exception of mists and fogs, could ever make their appearance. All the moisture evaporated in such circumstances during day, would be returned to the earth in the forms of dew and falling mist during night. Even in our windy climate, the proportion of moisture, averaged for the whole of Great Britain, which is re-

turned to the earth in the form of dew, (and it is only during intervals of perfectly calm, or nearly perfectly calm weather that dew is deposited,) has been estimated by Dr Thomson, to be only 4 inches out of the total 36.

Nor does the existence of wind without the co-operation of other circumstances necessarily produce clouds. For instance, if the whole surface of the earth was level like that of the ocean, and if the direction of the wind was always from a cold towards a warmer climate, and the temperature of the different aerial strata was always such, that a colder and heavier atmosphere never came to rest over one that was warmer and lighter, no clouds could be formed. But, as this is not the case, and as the kind of weather at any given time and place, is a result affected and modified by a variety of antecedent and existing circumstances, which may be acting more or less either in union, or in opposition to each other, it is necessary, in order to a correct understanding of meteorological phenomena, that we should explain the modifications, which different degrees of velocity in the atmospheric current may be expected to produce.

In general then it may be remarked, that whatever effect a wind of moderate velocity is calculated to produce upon the hygrometric condition of the atmosphere, will be increased by every increment in its velocity, and diminished by every decrement. Thus, if the wind blows from a warm towards a cold climate, great rapidity of motion, by allowing less time for cooling, will transport a warm atmosphere to a cold climate with less diminution of its previous tempera-

ture than if it moved with moderate velocity. Consequently, it must undergo a greater diminution of temperature and of capacity of moisture, (and which must occasion a proportionally greater amount of rain,) before being accommodated to the temperature and aqueous capacity of the air in the climate to which it has been transported. Hence, one reason why strong southerly winds, particularly during the winter season, are more productive, in this and all northern climates, of clouds and wet weather, than gentle gales from the same direction.

Again, every increase to the strength of the wind renders the unevenness of the earth's surface more effective in robbing the air of a portion of its moisture in the following ways :—1. It causes the atmospheric current to surmount a greater number of hills and elevated lands in a given time. 2. By increasing the atmospheric agitation, it drives the particles of precipitated vapour composing mists and clouds together, so as to form drops of rain ; and thus, by increasing their gravity, accelerates their descent to the surface of the earth.

But, while every increment to the velocity of the wind renders the unevenness of the earth's surface more effective in robbing the air of a portion of its moisture, it, at the same time, promotes evaporation, and thereby more speedily replenishes it again with humidity. Thus, though the atmosphere may be rendered much undersaturated in its passage, during windy weather, over hills and elevated lands, humidity is thereafter supplied to it according to the law, that evaporation from all moist surfaces proceeds with

greater rapidity according as the incumbent atmosphere is hygrometrically drier. Of course, the more rapidly, and the more completely the air is robbed of its moisture in passing over mountains or elevated lands, the more is evaporation subsequently accelerated.

Again, during calm weather, evaporation only proceeds with a rapidity proportional to that with which the vapour is carried off, and intermixed with the incumbent atmosphere in consequence of its tendency to diffuse itself equally. Now, this tendency to aerial diffusion is mechanically assisted during windy weather, and evaporation is accordingly promoted, in consequence of fresh undersaturated portions of air being then brought successively, and rapidly, into contact with the evaporating surface. Owing to this mechanical assistance, Saussure found, by experiments performed at Geneva, that wind moving at the rate of 22 feet in a second, triples the quantity evaporated in calm air.

The aggregate amount of water precipitated from the atmosphere upon the earth's surface, must be exactly the same as that which is raised therefrom by evaporation. Consequently, whatever increases evaporation, whether it be increase of temperature, or increase in the velocity of the wind, must correspondingly increase the aggregate amount of water precipitated. But though this be the case, the proportion of aqueous vapour which passes into the form of cloud before descending, relative to the aggregate amount of water evaporated, is much greater in climates where windy weather prevails, than in those of an opposite character.

The atmospheric variation of temperature during day and night, is found to diminish with the perpendicular altitude above the surface of the ground; and this variation near the surface of the ground, is much greater in calm, than it is in windy weather. Owing to the agitation and intermixture of the various aerial strata during windy weather, the difference between the temperature of the higher and lower atmospheric strata is restricted both by night and day, chiefly to the decrease of one degree for every 300 feet of perpendicular ascent. During calm weather, however, while the temperature of the lower aerial strata is much higher than those at a greater altitude during day, the reverse, as was formerly stated, is the case by night. Now, as the hygrometric condition of the atmosphere, and of its various strata, is chiefly regulated by variations of temperature, it is obvious that during calm clear weather, the difference between the hygrometric dryness by day, and dampness by night, of the lower atmospheric strata, will be much greater than during windy and cloudy weather. Hence, during calm clear weather, though the lower atmospheric strata may become much undersaturated during the heat of day, they frequently become so much oversaturated as to precipitate humidity during the coldness of night; and accordingly, a greater or less proportion of the water evaporated from the earth's surface during day, is gradually returned to it by deposition in the form of dew during night, without ever passing into the state of cloud. In inland champaign countries where long calms prevail, and in warm climates, during what is called the dry season, this condition

of the atmosphere frequently continues for weeks and months together, without any of those elevated clouds being formed, from which alone rain is precipitated. During windy weather, however, when, for reasons already explained, the temperature of the aerial strata immediately incumbent upon the earth's surface does not sink lower during night, than that of those at a greater altitude, no dew falls; and consequently, all the moisture then evaporated, (and which is greater than in the opposite circumstances,) before descending, passes into the state of cloud, and is returned to the earth in the forms of rain, snow, and hail.

The preceding observations sufficiently explain the reasons why windy weather is peculiarly productive of clouds and rain; and why a prevailing stillness in the atmosphere is favourable to dry weather and a cloudless sky. Accordingly, it is observed, that in windy climates, in windy years, and in windy seasons of the year, there is more cloudy and wet weather than in those of an opposite character. Last winter (1833-4) was remarkable for the prevalence of high winds, and their direction being chiefly from rainy points, viz. between south and west inclusive, it turned out, in accordance with the principles we have been explaining, to be one of the wettest winters on record, over the whole of Great Britain and Ireland.

Before concluding this chapter, several not very important circumstances which require explanation, may be noticed. Thus it once occurred to me, that the formation of clouds in the higher regions of the air might be accounted for upon the principle, that as aqueous vapour has a greater capacity for heat, and is

specifically lighter than air in the proportion nearly of 5 of the former, to 8 of the latter, aqueous vapour ought to rise in the atmosphere till increasing coldness, by condensing it into the visible and heavier state of cloud, prevented its farther ascent. But though the greater specific lightness of vapour than air, acting in conjunction with the greater calorific capacity of the former, and consequent susceptibility of losing, or gaining a larger proportion of heat, with an equal diminution, or increment of temperature than the latter, may possibly not only determine the height in the atmosphere to which vapour can ascend, but also the proportions which at different temperatures can exist in invisible solution in a given space; still there are facts which demonstrate that clouds are not the result of their joint agency. For instance, if aqueous vapour, in consequence of being specifically lighter than air, had a tendency to ascend till it was condensed by coldness in the higher regions of the atmosphere, an unclouded sky, particularly at sea, would never be seen. In such circumstances, the condensation of vapour, and the formation of cloud in the higher regions of the atmosphere, would be constantly going on, with a rapidity at all times proportional to the amount of moisture evaporating underneath. Now, the continuance of fair weather, and a cloudless sky, for weeks, and even months, (which frequently occurs in more southern latitudes,) not only on shore, but also at sea, is incompatible with such a hypothesis. Indeed this fact leads us to infer, that the ascending tendency of aqueous vapour, arising from its being specifically lighter than air, is

counteracted when the atmosphere becomes saturated with moisture; and that any diminution of temperature, such as may be supposed to occur during night, or the fall of the year, affects the higher regions of the air so slowly and so slightly, in comparison with the lower, as merely to occasion a gradual subsidence of the aqueous vapour towards the earth's surface, without converting any part of it, unless assisted by other causes, into the visible form of cloud. Now, agreeably to the views we have already given of the formation of clouds, a continuance of fair weather, and an unclouded sky, for weeks and months, at certain seasons of the year, results either from there being little or no wind; or from its direction being favourable to dry weather, such as blowing from a cold towards a comparatively warm climate; or from a quarter in which it is robbed of humidity by passing over elevated mountains, or an extensive tract of dry land, without being proportionally replenished by evaporation from a watery surface underneath. On the other hand, the continuance of wet weather, which in certain climates often follows a continuance of dry weather; and in general, the frequency of wet weather, during particular seasons of the year, results from the direction of the wind being in the former case for a continuance of time, and in the latter, on frequent occasions, favourable to wet weather, such as blowing from the sea and a warmer climate.

From the preceding observations, it appears that clouds, without the assistance of some other cause of their formation, do not result from the tendency of aqueous vapour to ascend, in consequence of its less

specific gravity than air, till it gets condensed by coldness in the higher regions of the atmosphere. Nevertheless, I am disposed to think that this ascending tendency of aqueous vapour, must have some influence in bringing the elevated atmospheric strata sooner up to the point of saturation, than those near the earth's surface. For instance, let us suppose that all the atmospheric strata, to the elevation of 20,000 feet, are in an equal degree undersaturated with humidity. Let us suppose also that the temperature of these different strata, to that elevation, is remaining unchanged; that there is no wind; and that the atmosphere is getting gradually supplied with humidity by evaporation from a watery surface underneath. In this case, if the aqueous vapour was of the same specific gravity as air, and accordingly, had no tendency to ascend, the different atmospheric strata would be sooner brought up to the point of saturation, according as they were less elevated above the earth's surface. The circumstance, however, of clouds after a continuance of serene weather, first making their appearance in very elevated regions of the atmosphere, favours the opinion, that those strata are usually nearest the point of saturation; and when equally undersaturated with those below, are soonest brought up to the point of saturation; and, on these accounts, most apt to give birth to clouds when any reduction of temperature occurs. Thus, after a continuance of calm weather, and a cloudless sky, the first visible indication of an approaching change, is usually the appearance of *cirri*, the most elevated of all clouds.

To the preceding opinion it might be objected,

that if the atmospheric strata, at a great elevation above the earth's surface, are usually nearer the point of saturation than those underneath, the rising slope of a hill or elevated lands during windy weather, by uplifting and depressing the temperature, not only of the undermost strata of the atmospheric current, but of all those above, should cause clouds to form, not on or near the summits of hills and mountains, but in general, at a considerable altitude above them. While it may be admitted, agreeably to the second cause mentioned of the formation of clouds, that any slope or rising ground will have some effect in uplifting the whole atmosphere immediately vertical, while surmounting it, (and the stronger the wind the greater will be its influence in this respect,) still I am disposed to think, that the strata are uplifted in a rapidly diminishing degree, according as they are more elevated above the rising ground. Suppose a hill or the slope of the land were to rise from the sea-shore at an angle of 10 degrees from the horizontal, to the height of 1000 feet, I very much doubt if the atmospheric strata, at the elevation of two miles, would be uplifted 100 feet, or even so much while surmounting it, by any wind however strong. And this opinion is so far confirmed by the fact, that it has never yet been observed, that the barometer sinks less rapidly in ascending a mountain during windy weather, than it does during calm weather. If the preceding opinion be correct, it is obvious that the undermost strata, in consequence of being farthest uplifted, should be the most apt, in such circumstances, to become oversaturated, and to give birth to clouds. The disposal of

the air in such cases may be accounted for, partly by the retardation which the lower portion of the atmospheric current undergoes while approaching the rising ground, and partly by the increased velocity which the elasticity of the air communicates, when it has reached its summit.

It must be confessed, however, that it is difficult to explain how clouds, especially during windy weather and night, should be formed only between the elevation of 2000 and 20,000 feet above the level of the sea. The circumstance of the *stratus*, or fall-cloud, during calm clear nights beginning to form close to the surface of the ground, and gradually extending itself upwards, proves that the aerial strata nearest the earth's surface are equally susceptible, upon a sufficient reduction of temperature taking place, of giving birth to clouds, with those at a greater elevation. And the fact that the fall-cloud has seemingly no tendency to ascend in the atmosphere, until its component particles are expanded, and rendered specifically lighter by the heat of returning day, shows that the specific gravity of a cloud at its first formation may be so great as to cause it to float as low as the level of the sea.

During day, the greater augmentation of temperature which the atmospheric strata, near the surface of the ground, undergo, than those at a greater altitude, might be supposed to counteract, and prevent the formation of clouds within a limited distance of the earth's surface. But, during windy nights, when the surface of the ground, and the atmospheric strata thereupon incumbent, are apt to become at least as cold as the aerial strata at a greater elevation, it is

difficult to assign a satisfactory reason, why clouds never form nor float at a small elevation, such as from 100 to 600 feet above the level of the sea. This appears more remarkable, when it is considered, that clouds are principally formed when the wind blows from a warm towards a cold climate. In this case, the lower portion of the atmospheric current, by communicating in its progress with a colder and colder surface underneath, must have its temperature and capacity for moisture gradually reduced. Hence it might be anticipated, that, however much undersaturated previously, its hygrometric condition would be ultimately brought up to the point of saturation; and, thereafter, if the same cause continued to operate,—that is, if the wind continued to blow from the same direction,—it seems reasonable, *a priori*, to expect, that clouds should either be formed amongst the undermost aerial strata, or that moisture should be precipitated on the earth's surface. Moreover, the fact of no clouds making their appearance, in such circumstances, under 1500 feet above the level of the sea, is more remarkable when it is considered, that the reduction of temperature, above mentioned, affects the aerial strata nearest the ground soonest, and to the greatest extent, and all those above later, and in less degree, according as they recede upwards. And hence, reasoning, *à priori*, it might be anticipated, that the formation of clouds, in such circumstances, should always commence at the surface of the ground, and extend upwards; whereas, with the exception of the *stratus*, which only originates in still weather, their formation commences generally be-

tween 8000 and 20,000 feet above the earth's surface, and subsequently extends downwards.

The circumstance under consideration, viz. why clouds never form nor float, during windy nights, at a lower altitude than 1500 feet above the level of the sea, we do not pretend to be able satisfactorily to explain. It may possibly, however, result from the influence of various causes, such as the following, operating more or less in union with each other.

1. The principal component materials of the surface of the earth, and also the saline ingredients contained in the ocean, exert an attractive force upon moisture dissolved in the atmosphere; and the air, while it also exerts a similar attractive influence for moisture, has less power, according as it is nearer the point of saturation, in resisting that of the subjacent earth and sea. Now, as all attractive or repulsive forces, exerted by one body upon another, diminish as the square of the distance between them increases; the attraction exerted by the earth and sea, upon the aqueous vapour contained in the air, should become less, as the square of the distance, upon receding upwards from the earth's surface, increases. Hence, it is not improbable, that when the wind blows from a warm towards a cold climate, and the transported air gradually becomes damper, and consequently, less able to retain its humidity, the earth and sea, according to the principle upon which hygrometers are usually constructed, may at length begin to abstract moisture from the lower atmospheric strata; and the amount abstracted should increase as they approach the point of saturation. Owing to this abstraction of

humidity, the lower atmospheric strata, which, in consequence of greater proximity to the abstracting surface, should be most affected thereby, may, in general, be kept somewhat drier than the point of saturation, when the more elevated strata, in consequence of being less under the influence of the earth's attraction for moisture, may become so much oversaturated, as to give birth to clouds and rain.

As an attractive influence subsists between caloric and humidity, it may possibly be owing to the superior coldness of the ground relative to that of the incumbent atmosphere, assisted, perhaps, by the stillness of the air, that the moisture composing the *stratus*, and fogs in general, is so slowly attracted from the lower aerial strata by the subjacent earth.

2. The circumstance previously adverted to, of the elevated aerial strata becoming sooner saturated with moisture than those underneath, in consequence of the ascending tendency of aqueous vapour, arising from its less specific gravity than air, may also have some influence in producing the phenomenon under consideration. Thus, when the wind blows from a warm towards a comparatively cold climate, even though the aerial strata nearest the ground may undergo a greater reduction of temperature in a given time, than those at a considerable altitude; still, the greater proximity of the latter to the point of saturation, may cause them to become first oversaturated with humidity.

3. Provided the conjecture which we formerly advanced be correct, viz. that above a certain altitude, the velocity of the atmospheric current gradually di-

minishes; the intermixture of the upper with the lower atmospheric strata, according to principles explained when treating of the fourth cause of the formation of clouds, may also assist in causing the elevated aerial strata to become sooner saturated with moisture, so as to give birth to clouds and rain, than those underneath. And when once clouds are formed, the continuance of the intermixing process, in consequence of the heat evolved during their formation, and afterwards arrested by them, may account for the perpetuation of the formation of clouds in the higher regions of the atmosphere; while the air near the earth's surface remains undersaturated with humidity, and free of clouds.

4. The fact of all clouds formed during windy weather, floating at an elevation of at least 1500 feet above the level of the sea, proves, that the specific gravity of such clouds is never so great as to cause them to descend nearer the earth's surface. Hence it may be inferred, that though small quantities of moisture may be precipitated from the atmosphere into the vesicular form underneath the above altitude, still those vesicles may rise to that altitude, before being concentrated in sufficient quantities to form a visible cloud.

5. Judging from the fact of the amount of rain that falls being greater, as estimated by rain gauges, and the drops being larger, the nearer we approach the surface of the earth, and the lower the earth is at the place of observation, it seems probable, that descending rain possesses the property of attracting, and thereby withdrawing a portion of the aqueous vapour

from the air; and consequently, of undersaturating the lower atmosphere through which it passes in its descent to the earth.

The circumstance of clouds never making their appearance at an elevation much higher than 20,000 feet above the level of the sea, may possibly be owing, either to the coldness and lightness of the air at that altitude being such, that aqueous vapour cannot rise to a greater elevation, in consequence of its then tendency to condensation. Or, provided aqueous vapour ascends much beyond that altitude, its quantity may be so small beyond that elevation, that when precipitated from the atmosphere by a reduction of temperature, and thereby increased in specific gravity so as to descend, it may fall a considerable distance before the widely separated aqueous particles can unite; and after uniting, before they congregate in sufficient quantity to form a visible cloud. This last result may be conceived to take place at the altitude where the *cirri*, the most elevated, as well as the thinnest and most transparent denomination of clouds, make their appearance.

At what degree of coldness moisture becomes incapable of existing in the state of vapour, I do not know. But as aqueous vapour has a greater capacity for heat, and consequently during an equal reduction of temperature, must lose a larger proportion of caloric than air; and as the specific gravity of bodies increases during a given reduction of temperature in proportion, or nearly in proportion, as they part with caloric, it is obvious, that at some unknown elevation, and which will vary with the latitude and season of

the year, according as the temperature at that elevation varies, aqueous vapour must become specifically as heavy as air, and consequently will thereafter have no tendency to ascend higher. Hence it may be inferred, that no aqueous vapour can exist in the atmosphere beyond the altitude where the degree of coldness is such that aqueous vapour becomes specifically as heavy as air.

The only farther circumstance which we purpose to notice in this chapter is, that when a strong wind blows from a warm towards a comparatively cold climate, rain, on some occasions, only begins to fall, and on others, falls more copiously after the wind has somewhat abated, or perhaps altogether ceased, or even for a short time after it has changed to a dry direction, than it did, so long as it continued high. The explanation of this fact may depend upon the separate, or conjoint influence of the following circumstances:—1. When the wind blows strongly from a warm towards a cold climate, a warmer atmosphere is thereby transported to a cold climate, than what would otherwise have there existed. And though the temperature of the air may be getting gradually reduced during its progress thither, still the heated atmosphere may not acquire the reduced temperature of the climate to which it has been transported, till a considerable time after the wind has abated, or altogether ceased, or perhaps even changed its direction. Now, either of these events may occur before the temperature and capacity of the elevated aerial strata for moisture, is so much reduced as to precipitate a sufficiency of humidity into the form of clouds to produce rain.

The heated atmosphere brought by the wind may have been previously considerably undersaturated; and the reduction of temperature which it sustains during its rapid transportation to a colder climate may be insufficient, or little more than sufficient, to bring its hygrometric condition up to the point of saturation. In such circumstances, the continuance of the reduction of the atmospheric temperature, after the wind has ceased, or changed its direction, may occasion clouds and rain in abundance, while the reduction of temperature which it previously underwent during its transportation to a colder climate, may have produced no rain, and few clouds of any considerable depth, or density. When rain attends a wind blowing from a colder climate, it can only be explained upon the above principle, viz., that the more elevated aerial strata have been previously transported from a warmer climate, and are still undergoing a reduction of temperature.

2. The oversaturation of the atmosphere, and consequent additional formation of clouds, arising from the sinking down and intermixture of the colder atmospheric strata above, with those warmer strata below, where the clouds have already begun to form, as was explained when treating of the fourth cause of the formation of clouds, may also assist in rendering clouds, and the fall of rain, more abundant after the wind has abated, or even changed its direction, than what they were so long as it continued high.

3. The velocity of a high wind must in some degree prevent the sinking down and intermixture of colder air above, with any aerial stratum that happens

to be warmer below. Hence, in all the cases before enumerated, when the formation of clouds depend upon, or is assisted by, the intermixture of saturated, or nearly saturated, aerial strata of different temperatures, the subsidence of the wind should for a short time be accompanied by an increased formation of clouds, and a more copious fall of rain. Accordingly, it is frequently observed, that so long as the wind continues high, clouds are not formed of sufficient depth and density to produce rain. On such occasions, when the wind abates, the assistance of the intermixing process rapidly increases the density of the clouds already in the process of forming, and causes them to descend to a lower level. At length their component particles becoming too contiguous to remain separate, begin to unite. Their specific gravity being thereby augmented, they now rapidly descend; and partly by means of farther unions; and partly by condensing and receiving additions from all aqueous particles which they either attract, or come in contact with in their fall, they ultimately reach the surface of the earth in the form of drops of rain.

CHAPTER IV.

ON CIRCUMSTANCES ERRONEOUSLY SUPPOSED TO PRODUCE CLOUDS.

Professor Playfair, in his Outlines of Natural Philosophy, after explaining the ratio in which the capacity of air for moisture varies with alterations of temperature, states, "*If therefore large portions of the atmosphere, of different temperatures, and saturated, or nearly saturated, with humidity, be driven against one another by contrary winds, the consequence must be a precipitation of humidity, or the formation of clouds.*"

In the passage above quoted, the reader might be led to believe, that Playfair supposes, that two large portions of atmosphere, on the same horizontal level, and of different temperatures, might be driven against one another by contrary winds, just as if they were projected by the force of immense bellowses placed opposite each other. This, however, being contrary to the principles which regulate the direction of winds, never happens in nature, and therefore is never the cause of the formation of clouds.

The formation of clouds, according to the Huttonian theory, is also supposed to arise *from the collision of the upper and lower halves of the atmosphere, which, agreeably to the commonly received opinion,*

are supposed to be always moving in opposite directions. Thus Playfair says: "Professor Leslie has shown that the collision of opposite currents of air, of different temperatures, may furnish a supply sufficient for the production of the heaviest rain." *Experiments on Heat and Moisture,* p. 130. And Playfair adds, "The mixture of different portions of air is likely to take place most frequently, where the two opposite currents already mentioned come in contact with one another. This is at the height of 18,000 feet and upwards."

When treating, in the preceding chapter, of the fourth cause of the formation of clouds, we endeavoured to show that it was only when the lower half of the atmosphere blew from a cold towards a comparatively warm climate, such as is exemplified by monsoons and sea and land breezes, that an opposite current in the upper half of the atmosphere can simultaneously exist. And we demonstrated, that in the opposite circumstances, when the lower atmosphere blows from a warm towards a cold climate, it is physically impossible that there can be simultaneously a contrary current in the upper half of the atmosphere. Now, as by far the greatest proportion of rain in this, and almost all other climates beyond the tropics, falls when the lower atmosphere blows from a warm towards a comparatively cold climate, it is obvious, that the clouds and rain, produced in such circumstances, do not result from the collision of opposite currents simultaneously existing in the upper and lower halves of the atmosphere.

But supposing, for the sake of argument, that the

commonly received opinion, of opposite currents always existing in the upper and lower halves of the atmosphere, were correct, the collision of the upper and under atmospheric currents should be as great when the former is blowing from a warm towards a cold climate, and the latter from a cold towards a warm climate, as it is in the opposite circumstances. But we have seen, as in the example previously given of the Mistral, at Marseilles, that clouds are only formed when the lower half of the atmosphere blows from a warm towards a cold climate; and that they dissolve and disappear in the reverse circumstances. Hence collision of the upper and lower atmospheric currents is not the cause of the formation of clouds.

When we come to treat of the causes and principles of winds, it will appear in those cases where opposite currents in the upper and lower halves of the atmosphere exist, that at the plane which separates the two halves, the atmospheric strata must be in equilibrium, and can have no horizontal motion whatever. And it will also be evident, that, though the horizontal movements of the upper and lower halves of the atmosphere may gradually increase with the distance from the plane which separates them, still, for a considerable space on either side of it, the motion must be very slow; and accordingly, collision between the upper and under atmospheric currents can hardly be said in such circumstances to take place. In short, the sinking down and intermixture of the superior with the inferior aerial strata, which, as was explained when treating, in the preceding chapter, of the fourth cause of the formation of clouds,

can only take place when the aerial particles of the former are colder and heavier than those of the latter, after making due allowance for the different degrees of atmospheric compression to which they are subjected, is totally a different thing from the collision spoken of by meteorologists. This is evident from considering, that the sinking down and intermixture of the superior with the inferior strata, must go on so long as the former are colder and specifically heavier than the latter. And this may continue for a considerable time after the atmospheric currents have subsided into a perfect calm.

Another circumstance, erroneously supposed to be a cause of the formation of clouds, and the falling of rain, is *a change of wind.* The most important facts upon which this opinion is founded, are the following :—1. *During calm, or nearly calm weather, rain, particularly in warm climates, or, in the summer season, in temperate latitudes, is usually preceded and ushered in with a breeze, and not unfrequently by a greater or less change in the direction of the wind.* 2. *In intertropical climates generally the rainy season occurs when the sun approaches the zenith, at which time the winds are most variable.* 3. *The change of the monsoons in the East Indies is always accompanied with the formation of dense clouds, and heavy falls of rain ; whereas when the trade-winds blow uniformly, hardly any rain falls.*

In support of the notion, that a change of wind is a cause of rain, Professor Playfair, in his Outlines of Natural Philosophy, says : " There is in our climate hardly any instance of rain without a change of wind,

and very rarely a change of wind without rain in a greater or smaller quantity." This statement of Playfair's is so far from being correct, that he must certainly have made it without any examination of the facts himself.

Owing to the peculiar situation of Britain, surrounded by the sea on every side, together with the impossibility of ascertaining what is, or may previously have been, the precise direction and force of the wind in the upper half of the atmosphere, we cannot for certain predict, even though the direction of the wind in the lower half of the atmosphere be given, that we shall have either dry or wet weather on any day of the year. But, judging from my own observations, the chances of rainy, or of fair weather, are obviously greater or less, in proportion as there exists at the time, and immediately previous, a more or less favourable combination of circumstances for producing one or other of these results. In short, I feel warranted in stating, that even in any part of Great Britain, a knowledge of the general principles which we have already explained regarding the causes which tend to produce an oversaturated state of the atmosphere with regard to humidity, together with a knowledge of the direction and force of the wind, and the distance of the place of observation from the sea, and its position in relation to surrounding elevated lands, afford us the best means of accounting for all changes of weather. Thus, at Glasgow, where my observations have been made, (though the same rule, for obvious reasons, will not apply to parts of the island differently circumstanced with regard to dis-

tance from the sea, and intervening high lands in different directions,) when the wind blows from a warm direction, and from the nearest sea, such as from the south or south-west during the coldest period of the year, (and the stronger it blows the more certain is the result,) the general character of the weather is warm for the season of the year, but cloudy and wet. And instead of there being hardly any instance of rain in our climate without a change of wind, as Playfair states, the weather, so long as the wind blows from that direction, during that season of the year, usually continues wet, showery, and unsettled, with only casual dry days, and these chiefly when the wind abates. On the contrary, when the wind blows from the opposite quarter, viz., from the north, or north-east, during the same season of the year, the general character of the weather is cold, and dry, with only casual wet or snowy days; and these are usually attended with a low state of the barometer, and a considerable force of wind. And, instead of a change of wind from the former direction to the latter being productive of rain in a greater or smaller quantity, as ought to be the case if Playfair's statement were correct, almost every person knows that it is usually, and almost immediately, productive of dry weather.

On continental coasts, where a great extent of land lies in one direction, and the ocean on the other, such as on the coast of the United States of America, the point from whence the wind blows, in accordance with the principles already explained, determines the kind of weather. In the United States of America,

when the wind blows from the land, especially if its direction be somewhat to the north of west, dry weather, and a cloudless sky, particularly during the cold season of the year, permanently continues; whereas, when it blows from the ocean, especially if its direction be somewhat to the south of east, the general character of the weather is cloudy and wet. In such cases, the mere change of wind separately considered, has no perceptible influence in forming clouds and causing rain. No sooner does the wind shift from the ocean to the land, than the wet weather ceases, and the clouds gradually dissolve into invisible vapour. And, on the contrary, when the wind shifts from the land to the ocean, the previously clear sky, very soon becomes overcast with clouds, and rainy unsettled weather commences.

The instance formerly given and explained of the opposite kinds of weather experienced during winter at Marseilles, according as the wind blows from the north or the south, also confirms the opinions we have advanced. Thus, a change in the direction of the wind at Marseilles, during the cold season of the year, from north to south, is uniformly attended, or very soon followed, by the appearance of clouds, and the falling of rain. But when it changes, during the same season of the year, to the opposite direction, instead of producing rain in greater or smaller quantity, as Playfair's statement would lead us to expect, the clouds disappear with astonishing rapidity.

In the preceding examples, it is obviously the quarter to which the wind shifts, and not the mere change, which determines the character of the wea-

ther. But let us take cases where the dryness of the direction to which the wind veers, cannot be assigned as the reason why the change is not accompanied with rain in greater or smaller quantity.

At Kingston, in the island of Jamaica, during what is called the dry season, viz. from November till April, those gentle winds, denominated Sea and Land breezes, occur alternately in succession; and though the direction of the wind, during that lengthened period, changes twice every twenty-four hours, still, with the exception of clouds formed over the distant mountains, according to the second mentioned cause of their formation, there is almost constantly a cloudless sky, and hardly ever a drop of rain.

In like manner, during our finest and clearest weather, such as we frequently have during the summer months, the direction of the wind frequently shifts in our climate several times in the course of a day; but these changes, so far as I have observed, have no influence in forming clouds, and causing rain. I shall only farther add, that after carefully comparing, by means of a meteorological table which I have kept, the coincidences between a change of wind, and the formation of clouds, I have found the discrepancies so numerous, as to convince me, that the coincidences, save those which were more properly referable to other causes, and which were partly balanced by equally objectionable discrepancies, are merely accidental. Hence, I have come to the conclusion, that in this climate, contrary to Playfair's statement, a change of wind, considered separately from its direction and velocity, is never the cause of the formation of clouds,

and the falling of rain; though, as I will shortly have occasion to show, the formation of clouds and the falling of rain is frequently the cause of a change of wind.

We shall now advert to the several phenomena upon which the hypothesis we have been considering is founded; and as we proceed, will illustrate our subject, by attempting to give some plausible explanation of them.

The first point then to be considered is, *that during calm, or nearly calm weather, rain, particularly in warm climates, or in the summer season in inland temperate latitudes, is usually preceded and ushered in by a breeze or gust of wind; and not unfrequently by a greater or less change in the direction of the wind.* I am inclined to think that it is principally owing to this and analogous facts not being properly understood, that a change in the direction of the wind has been supposed to be the cause of the formation of clouds and the falling of rain; whereas, as I shall endeavour to show, the previous formation of clouds and the falling of rain, is, in all such cases, the cause of the breeze and of the change of wind.

When we come to treat of the causes of wind, it will appear, that, provided the barometrical pressure, (that is, the atmospheric pressure as estimated by a barometer,) at all equal altitudes above the level of the sea were the same, there could be no wind; for, in that case, the atmosphere would be everywhere in equilibrium, and could have no tendency to move in one direction more than in another. On the contrary, at whatever equal altitudes any difference in the

barometrical pressure takes place, the atmosphere, at such altitudes, in obedience to the preponderance of lateral pressure, will begin to move horizontally in order to restore the equilibrium, from where the pressure is greater to where it is less. The proximate cause therefore of atmospheric currents, *is unequal barometrical pressure in different places, at equal altitudes above the level of the sea.*

Now, owing to the expansibility of air by means of heat, a perpendicular column containing a given amount of warm air, is longer than one containing a similar amount of cold air ; and consequently, the upper portions of the former, from wanting sufficient lateral support, must flow over upon the latter. But this, while it diminishes the barometrical pressure of the longer columns, proportionally increases that of the shorter. And accordingly, while the upper portions of the longer columns of warm air are flowing over upon the top of the shorter columns of cold air, an equivalent extent of the lower extremity of the shorter columns, in obedience to the preponderance of barometrical pressure, moves in the opposite direction.

The preceding observations show, that an equal barometrical pressure at all equal altitudes above the level of the sea, could only exist, provided the temperature of the atmosphere at all equal altitudes around the globe were alike. This, however, can never happen. The causes of difference of temperature over different parts of the earth's surface, are numerous, and ever varying with regard to each other during the alternations of day and night, and the dif-

ferent seasons of the year. And as the various temperatures of the different parts of the earth's surface, whether land or water, are slowly communicated upwards to the portion of air immediately incumbent, it is impossible that an universal equilibrium of the atmosphere can ever take place. In conformity, therefore, with these observations, we lay down the general principle, *that whatever produces a simultaneous difference of temperature in different portions of the atmosphere, at equal altitudes above the level of the sea, necessarily gives rise to inequalities of barometrical pressure, and thus remotely becomes the cause of wind.*

With these preliminary remarks, we are now prepared to understand how the supervention of clouds, and the falling of rain, at one place and not at another, should become the cause of a breeze and of a change of wind.

When clouds, whether formed during night, or transported by aerial currents, supervene any district of a country, the surface of the ground, and the portion of the atmosphere underneath them, receives a less proportion of solar heat during day, than those places over which no clouds are formed. Hence the temperature becomes higher in the latter localities than in the former; and the atmospheric columns, agreeably to the expansibility of air by means of heat, become more expanded upwards over the latter than over the former. In like manner, the descent of moisture in the forms of rain, snow, or hail, adds to the effect, by bringing down and communicating to the lower atmospheric strata, in its passage, a portion

of the coldness which it acquired at the altitude at which it was formed. Now, the depression of temperature which the lower atmospheric strata undergo, is necessarily accompanied with a corresponding condensation, which must produce a sinking downwards of the whole superincumbent atmosphere. Hence, in accordance with our previous remarks, the upper extremity of the atmospheric columns where no clouds are formed, and no rain has fallen underneath, must flow, in obedience to the force of gravity, towards the places where clouds are formed and rain has fallen. And on the contrary, in obedience to the preponderance of barometrical pressure, the lower portion of the atmosphere must blow from where rain has fallen and condensation has taken place, to where no rain has fallen and no condensation taken place.

Now, as the upper portion of the air all around where rain has fallen, moves towards the place where the greatest condensation and sinking down of the atmosphere occurs, the barometrical pressure there becomes greatest. Hence, the direction of the breeze at the surface of the earth, (except for modifications resulting from some more general cause of wind,) is from where the condensation under the cloud is greatest, to every point around, where no rain has fallen, and no condensation has taken place. Unless, therefore, the previous direction of the wind, and the point of greatest aerial condensation under the cloud, and the place where the observer is situated, be all in one straight line, the direction of the wind, upon the near approach of the cloud, will shift, at the surface of the earth, more or less towards the quarter where the

falling of rain has produced the greatest aerial condensation, and consequently, where the barometrical pressure under the cloud is greatest.

For the sake of illustration, let us suppose that the direction of the wind, by which the cloud is propelled, is from south to north, and that a meridian line, passing through the centre of the cloud from north to south, is the line of greatest aerial condensation, and greatest barometrical pressure; it is obvious in this case, that, to an observer stationed on the ground, to the east or west of that line, the direction of the wind, (that is, in meteorological language, the direction from which the wind blows,) will shift, on the near approach of the cloud, more or less towards the line of greatest condensation; and the degree of shifting, under the anterior margin of the cloud, will be greater or less, according as the place of observation is farther eastward or westward of the line of greatest aerial condensation. It may be farther noticed, that after the rain has continued for some time, and the aerial condensation, and barometrical pressure, has become about equal for a considerable distance around the place where the observer is situated; the local and transitory cause of wind, produced by the falling of rain, comes to have less influence in modifying, and altering the previous more general cause of the atmospheric current. Hence the reason, that though the wind, at the surface of the earth, may augment its velocity, and, in some degree, change its direction upon the approach of a shower, still, after the rain has continued for a short time, it

is usually observed gradually to subside to its previous velocity, and to regain its former direction.

Again, the force of the breeze, occasioned by the falling of rain at one place and not at another, is determined by the conjoint influence of two circumstances, viz. the difference of barometrical pressure at the respective places, and their proximity to each other. The greater the difference of barometrical pressure between the two places, and the nearer they are to each other, the stronger is the breeze, and *vice versa.* So great is the influence of proximity in this respect, that an extremely small, and almost imperceptible difference of barometrical pressure between two contiguous places, will give rise to a considerable breeze of wind; whereas, when the places are very distant from each other, a great difference in barometrical pressure will produce only an inconsiderable effect. Now the place where the difference of barometrical pressure, occasioned by the falling of rain, is greatest within a given distance, is under the skirts of the cloud. Hence the reason that a shower of rain in calm weather, such as usually prevails in warm latitudes, or in inland champaign countries, is commonly preceded, and ushered in by a breeze, or gust of wind; and when wind previously existed, by an increase to its velocity. And the reason why these effects are usually stronger, and more observed in hot climates, and in the summer season in temperate latitudes, than in cold climates, or in the winter season in temperate latitudes, is because the sinking of temperature, and the aerial condensation

occasioned by the falling of rain, is usually greater in the former circumstances than in the latter.

The preceding observations satisfactorily demonstrate, that it is not the change of wind, as is commonly supposed, which in warm and nearly calm weather is the cause of rain, but that the rain, in such circumstances, is frequently the cause of a change of wind. And though our remarks, in illustrating this point, may appear unnecessarily lengthened, still, by accounting for other attendant phenomena, subsequent explanations upon analogous points will be rendered unnecessary.

We will now proceed to consider the second fact upon which the hypothesis that a change of wind produces rain is founded, viz. *that in intertropical climates generally, the rainy season begins when the sun approaches the zenith, at which time the winds are most variable.*

Before commenting upon this fact, it may be proper to describe the succession of weather which occurs periodically in warm latitudes. And as an example of what happens generally in other intertropical climates, we will select the weather at Kingston, situated on the south side of the island of Jamaica, in 18° north latitude. It must be recollected, however, that in applying the following description of the weather to other intertropical climates, allowance must be made for the peculiarities of local situation in reference to sea and land, and the difference in the time of the year when the sun in different latitudes crosses the zenith.

Kingston, in the island of Jamaica, is visited annually with two rainy seasons, severally commencing

about the time the sun crosses the zenith. The first, or moderate rains, as it is commonly called, begins about the latter end of April or beginning of May, and lasts for about six weeks. It consists merely of transient showers, by no means frequent or of long continuance, and alternate dry weather. The second, or principal rainy season, begins about the middle of August, and does not terminate till the end of October, or middle of November. It consists chiefly of alternate heavy showers, continuing for an hour or two, and dry weather. It is during the principal rainy season only that hurricanes happen. They consist of very heavy rain and furious wind. In their most violent forms they seldom continue longer than a few hours; but when they assume a less formidable character, they sometimes last for perhaps two or three days without intermission. From the middle of November till the latter end of April, and also from the middle of June till August, which are usually denominated the dry seasons, a cloudless sky, except for clouds formed over the distant mountains, continues almost without interruption. And though at any time during these periods of the year an accidental shower may fall, such a thing is then of rare occurrence.

During the dry seasons, the sea and land breezes alternate in succession, both in the course of 24 hours, blowing on different days, and at different times of the day, with different degrees of force, sometimes very gently, and at other times with considerable vehemence. During the rainy season, the alternate regularity of the sea and land breezes is commonly, but not constantly, interrupted. Dead calms, accom-

panied with torrents of rain and lightning, are then of frequent occurrence. And upon the whole, if we except hurricanes, there is usually at Kingston less wind during the rainy, than during the dry season. In other intertropical climates, where the regular trade wind from east to west blows continually throughout the 24 hours, its regularity is in like manner more or less interrupted during the rainy season. Such is a brief description of the periodic succession of weather which occurs in intertropical climates.

From our previous observations upon the influence of rain in depressing the temperature of the lower atmosphere, so as eventually to give rise to inequalities in the barometrical pressure in contiguous places, it is obvious, that interruption to the alternate regularity of the sea and land breezes at Kingston, and also to the more uniform easterly trade wind which prevails in other hot climates, must be produced by the local and temporary influence of clouds and rain during the wet season. Even the amount of rain estimated by weight, which, in hot climates descends in a short time in particular spots, is so great as to cause slight simultaneous inequalities of barometrical pressure in different places at no great distance from each other. And this of itself is sufficient to disturb the regularity of the winds in hot climates. Now, when it is considered, that there is no apparent reason why the variableness of the winds, during the rainy season, should produce wet weather; and an obvious one why wet showery weather should produce variableness in the winds, the only admissible conclusion is, not that the uncertainty of the winds is the

cause of the showery weather, but that the showery weather is the cause of the uncertainty of the winds.

An inquiry of great meteorological importance, which is silently evaded by meteorological writers, and which we formerly left for subsequent consideration, here suggests itself. The inquiry alluded to is *into the cause of the rainy season in hot climates.* Why does the rainy season in intertropical climates generally commence when the sun approaches the zenith, and continue during what should otherwise be the warmest period of the year?

In advancing a hypothesis in order to explain this point, it is again necessary, for the sake of being understood, to anticipate our observations regarding the causes and principles of winds, by remarking, that the most general cause of wind is the gradual decrease of the mean annual temperature from the equatorial to the polar regions. The result of this decrease of temperature is, that the prevailing direction in which the lower half of the atmosphere moves, is from the polar towards the equatorial regions; and on the contrary, the prevailing direction of the upper half is from the equatorial towards the polar regions. And from the perfect equality, or rather, the nearly perfect equality of the mean barometrical pressure at the level of the sea in all latitudes, it is concluded, that the amounts of air transported by these opposite currents are equal.

Now, in order to perpetuate these opposite currents, and connect them together, so that the one should become the source from whence the other is supplied with air, it is obvious, that, according as the

upper aerial strata in the colder latitudes of the polar regions are supplied with warmer air from a southerly direction, so must the whole atmosphere be there slowly descending towards the surface of the earth. In like manner, according as the lower aerial strata in the warmer latitudes of the equatorial regions become heated, and uplifted by the insinuation of colder and denser currents from the north and south, which gradually get heated and uplifted in their turn, so must the atmosphere be there subjected to a gradual ascension from the surface of the earth. And thus the chain connecting the prevailing current of the upper half of the atmosphere from the equatorial towards the polar regions, and of the lower half from the polar towards the equatorial, becomes complete.

Judging from the length of time that the rainy season in intertropical climates continues, the breadth of the zone which it covers, must be somewhere between 1000 and 1500 miles. But this zone does not remain stationary. In consequence of the sun's declining gradually and successively on either side of the plane of the equator, to the extent of 23½ degrees in the opposite seasons of the year, the warmest latitudes, that is, those over which the sun, during the earth's diurnal rotation, becomes most vertical, and which correspond with the zone where the atmosphere is gradually ascending from the earth's surface, are continually shifting northward or southward, with the apparent path of the sun in the ecliptic. Now, judging from the circumstance of the rainy season, in intertropical climates, commencing generally upon the sun's approach to the zenith, and be-

ing at its height, in any given latitude, at the time when the atmosphere should have the greatest tendency to ascend perpendicularly, viz. about the time when the subjacent earth and incumbent atmosphere acquire their maximum temperature ; and which, according to analogy, is some time after the sun has crossed the zenith. And judging also from the circumstance of the rains gradually diminishing, and at length terminating, about the period when, from the increasing obliquity of the sun's rays, the given latitude can no longer be supposed to be one of those over which the atmosphere is ascending ; I conclude that the rains, during the rainy season in hot climates, are produced by the ascent of the atmosphere in the following manner.

The aqueous vapour which the atmosphere contains is carried up along with the ascending current, (just as smoke is carried up with the heated air from a chimney,) till the increasing coldness, consequent upon the rarefaction of the atmosphere as it rises, causes the invisible vapour to be precipitated into clouds. And these increasing in density by a continuance of the causes which produced them, at length discharge themselves in heavy showers of rain.

By inspecting a thermometer it will be observed, that, during summer, the atmospheric temperature, near the earth's surface, begins to sink immediately after the shower commences. This is owing to the rain bringing down a portion of the coldness it has acquired at the elevation from which it descends. The consequence of this sinking of the temperature in the lower atmosphere is, that the ascension of the

air, and the formation of cloud, is for a time suspended. Gradually, however, as the lower atmosphere again becomes heated, whether by the sun's rays, or by the emission of caloric previously absorbed by the earth, the ascension of the air and the formation of cloud again commences; and a similar renewal of causes and consequences to those above described goes on in succession.

The preceding observations explain the reason why the rainy season, in intertropical climates, consists chiefly of alternate heavy showers and dry weather. This alternation, however, is farther assisted by another circumstance. The immense quantity of caloric which is evolved during the conversion of invisible vapour into clouds, warms the atmospheric strata where this conversion takes place. And after clouds are formed, the temperature of the atmospheric strata in which they float is farther augmented by the solar heat arrested by them in its progress towards the earth's surface during day, and in its retrocession from the earth's surface during night. In accordance with these views, Humboldt, as was formerly stated, found in ascending, that the ratio in which the temperature of the air decreased, was less in the region of the atmosphere where clouds were formed, than what it was either below or above that altitude. This he ascribed to the evolution of heat which accompanies the formation of clouds. The consequence of this increased temperature in the region of the atmosphere where clouds are formed is, that the aerial particles at a greater altitude, which have not participated in this accession of heat, are relatively colder and heavier than those

below; and accordingly, begin to sink down and intermix with them, and thus add to the formation of cloud. Hence we see, that the formation of cloud, in intertropical climates, occasioned by the depression of temperature which the atmosphere sustains as it becomes rarefied in ascending, and which is comprehended under the second mentioned cause of the formation of clouds, gives rise to one of the cases explained, and included under the fourth cause of their formation, viz. an intermixture and consequent reduction to a mean temperature of different portions of saturated or nearly saturated air, of previously different temperatures. The co-operation of this additional cause of the formation of clouds, of course increases the amount formed, and assists in continuing the process of formation for a longer time. But while it does so, (and it has this effect in all climates,) it is at the same time preparing the atmosphere for an interval of dry weather. While the intermixing process is going on, the air is gradually getting robbed of a portion of its moisture. But the heat evolved during the formation of clouds, is at the same time gradually diffusing itself amongst the more elevated aerial strata, till at length those regions of the atmosphere become so much undersaturated as to be incapable of producing clouds, even with the aid of some slight intermixture, until again supplied with humidity by evaporation from the subjacent surface of the earth.

The third cause of the formation of clouds, viz. the reduction of temperature, and diminished capacity for moisture, which air undergoes by being transported by winds from a warm towards a comparatively cold

climate, and which, as formerly stated, is the principal one in temperate and cold latitudes, can hardly be conceived to have much influence in producing the rainy season in intertropical climates. The atmospheric temperature within the torrid zone undergoes very little alteration throughout the year. And the mean annual temperature within the tropics, which comprehends a zone 47 degrees of latitude in breadth, is so uniform, that the decrement, on receding from the equator to either tropic, hardly exceeds 8 degrees. Hence any reduction of temperature, and consequent diminution of capacity for moisture, which the air within the tropics can, in ordinary circumstances, sustain, by being transported from a warm towards a colder latitude, is so trifling, as to be altogether insufficient to account for the rainy season; and hardly sufficient to account for rain in any quantity, however small.

As the atmosphere is warmer, and therefore more elevated, in the latitudes where the rainy season is occurring, than in those either to the north or south, it is from this zone that the currents in the upper half of the atmosphere are continually diverging to the north and south. Hence, the supervention of cold currents in the upper half of the atmosphere cannot be admitted to be the cause of the rainy season. Nevertheless, it might be supposed, that the rainy season in intertropical climates might be accounted for, according to the fourth cause of the formation of clouds, without the aid of the supervention of cold currents in the upper regions of the atmosphere. Thus the ground and the aerial strata in its immediate

vicinity, might be conceived to acquire a much greater degree of warmth when the sun is vertical, than the more elevated atmospheric strata; and accordingly, that the formation of clouds might be produced by the latter sinking down and intermixing with the former. In answer to this objection it may be remarked, that if the formation of clouds during the rainy season occurred only on shore, and during day, the hypothesis above stated would be so far supported by these circumstances, as to give it some degree of plausibility. But when it is considered, that the formation of clouds, during the rainy season, goes on by night as well as by day, and particularly, as it occurs also at sea, where the lowest aerial strata, even during day, become very little, if at all, warmer than those at a greater altitude, it is obvious, that the hypothesis above given is insufficient of itself to explain the phenomena.

Again, if the formation of clouds during the rainy season be owing to an ascension of the atmosphere, the place of which is supplied by colder currents from the north and south, it might be asked by way of objection, why the rising up of the atmosphere over the land during the continuance of the sea breeze, and the ascension of the atmosphere over the sea adjoining the land during the land breeze, does not produce similar effects? This is a more difficult objection to answer than the preceding. It may be remarked, however, that there is a considerable difference between the cases. The rainy season continues from two to three months; and the hygrometric condition of the lower atmosphere, during all that period, never

rises much above the point of saturation. On the other hand, the sea breeze continues only for four or five hours, during the warmest period of the day; and before the atmosphere over the land begins to ascend, its temperature must be so much raised, that its hygrometric condition must be much drier than the point of saturation. Now, when it is considered, that the ascent of the atmosphere which makes way for the sea breeze, from being spread over a large surface, is so slow as not to be perceptible, (unless when obstructed by mountains in its progress inland,) and that the aqueous vapour contained in the ascending current, is ever tending to diffuse itself equally amongst the undersaturated aerial strata upwards, and downwards, and all around, it does not appear wonderful that no clouds should be formed by the slow ascension of a much undersaturated atmosphere during the short period of four or five hours, which is the length of time the sea breeze lasts.

In like manner, during the continuance of the land breeze, the air which comes off the land is colder, and heavier, than that which rests generally over the sea. On this account, it is probable, that there is no ascension of the atmosphere over the sea immediately adjoining the land; and that the upper extremity of the atmospheric columns over the land are wholly supplied by horizontal currents from a distance, and that the ascension of the atmosphere which supplies these lateral currents, may be so widely extended, and the ascent accordingly so slow, as not to be capable of producing clouds during the short time the land breeze continues.

Whether the preceding explanation of what we conceive to be the principal, and the most general cause of the rainy season be correct or not, the circumstance of its occurring at the time when the sun becomes most vertical, and accordingly, when the equatorial regions of the earth would otherwise become almost uninhabitable with heat, is obviously a Providential arrangement in creation to serve a useful purpose. Clouds, during this season, moderate the warmth, by acting as screens to intercept the scorching rays of a vertical sun, while the temperature of the earth is farther mitigated by the descent of rain, and by evaporation from its moistened surface. Thus we see that the rains, which are indispensably necessary in order to vegetation, occur in accordance with the prospective wisdom and beneficence manifested in all the other arrangements in nature, at the season of the year when their cooling influence is most required.

We come now to consider the third fact adduced in support of the hypothesis, that a change of wind is one of the causes of the formation of clouds, and of the falling of rain, viz., *that the change of the Monsoons in the East Indies, and Indian ocean generally, is always accompanied with the formation of dense clouds, and heavy falls of rain ; whereas, when the Monsoon blows uniformly, hardly any rain falls.*

In order to show the erroneous application of this fact, it may be premised, that the Monsoons are analogous to sea and land breezes, with this difference, that the former blows for many hundred miles in one direction, and takes a year to perform its revolution,

that is, blows half a year in one direction, and half a year in the opposite, whereas, the latter is only felt at sea within a few miles of the land, and extends only a few miles inland from the sea, and performs its revolution in the course of 24 hours. During the summer half of the year, the surface of the land in the East Indies, together with the incumbent atmosphere, become warmer than the surface of the Indian ocean, and the atmosphere thereupon incumbent; but during the winter half of the year, the reverse is the case. Hence the Monsoon, or season wind, (which is the meaning of the term,) according to the principle which determines the prevailing direction of the wind, blows from the ocean towards the land during the warmer half of the year; and from the land towards the ocean during the colder half. And in both cases, the upper half of the atmosphere is supposed to be moving in the opposite direction of the lower.

Now, when the Monsoon blows uniformly, whether from the land or from the ocean, (except during the rainy season, when the winds are always somewhat irregular,) the case is analogous to the one formerly explained, of a wind blowing from a cold towards a warm climate. The aerial particles of the upper half of the atmosphere are, in such circumstances, warmer, and lighter than those of the lower half; and accordingly, the former have no tendency to sink down and intermix with the latter, which, as formerly explained, is necessary towards the production of clouds, according to the fourth cause of their formation. Hence the reason, that when the Monsoon blows uniformly,

whether over the land or over the ocean, hardly any rain falls.

Immediately previous to the change of the Monsoon, the circumstances are different. In consequence of the velocity which the atmosphere has acquired, by moving in one direction for a considerable time and distance, the surface towards which the lower half is blowing has actually become colder than that from which it blows, for some time before the Monsoon changes. Thus, as the sun advances northward in the spring of the year, the temperature of the surface of the land in the East Indies, and other southern parts of Asia, though previously lower, gradually becomes higher than that of the Indian ocean, which forms their southern boundary. Now, the Monsoon, though its regular direction be from a cold towards a comparatively warm surface, in consequence of its acquired velocity, does not change from the land to the ocean, till some time after the surface of the land has become warmer than that of the ocean. During this period, therefore, a lighter atmosphere is brought by the wind, underneath a heavier one; and a sinking down and intermixture of the latter with the former, and the formation of clouds consequently takes place. The vacillation and unsteadiness in the direction and force of the wind, immediately before the change of the Monsoon, arises from the undulatory propagation of aerial currents, resulting partly from the difference of temperature which the atmosphere over the land undergoes during day and night, being much greater than that over the ocean; and partly from inequalities in the amount of heat evolved by

the unequal formation of cloud in different places. While this unsteadiness in the wind continues, though its prevailing direction, in obedience to the preponderating influence of its acquired velocity, be still from the land, the atmospheric columns over the ocean being then colder than those over the land, are not sufficiently elevated to support a current in the upper half of the atmosphere, from the ocean towards the land. The consequence of the co-operation of this circumstance with the prevailing direction of the wind from the land towards the ocean in the lower half of the atmosphere is, that the amount of air, in preparation for a blast, is accumulating, and the barometrical pressure increasing, over the Indian ocean; while the amount of air, and the barometrical pressure over the land, in the southern parts of Asia, is diminishing. This at length produces a general and decided reaction in the atmospheric current. Dense clouds, which for some days previous have been forming, and accumulating in masses proportional to the warmth of the climate, and the capacity of the air for moisture, are now seen rolling with appalling sublimity from the ocean towards the land. It is the change of the Monsoon. The wind with full reactive violence now blows a hurricane,—rain descends in torrents,—vivid flashes of lightning follow each other in rapid succession, and thunder in one continued roar, only distinguished by intervals of less loudness, lasts for several hours. This periodic thunder-storm is said to be so tremendous, in comparison with any thing of the kind ever witnessed in Britain, that when heard for the first time by natives of this country, it makes the stoutest

heart quake. And even those who after long residence have become somewhat accustomed to it, are impressed, during its continuance, with feelings of mingled awe and devotion.

After the storm has lasted for two or three hours the thunder ceases, but the rain continues for two or three days. As the southern portions of India are within the torrid zone, the south-west Monsoon, which sets in about the beginning of June, is the commencement of the rainy season. The two or three first days of constant rain are therefore succeeded by occasional heavy showers, which gradually increase in frequency and continuance till about the middle of July, when the rainy season is at its height. But after the description and hypothetical explanation previously given of the rainy season in intertropical latitudes, and as the causes which give birth to the rains are the same in India as in other warm climates, we need not farther enlarge upon this point.

Before concluding this subject, it may be remarked, that in climates, and in seasons of the year, when the winds are variable, from whatever cause arising, it may be easily conceived that a colder and heavier atmosphere may frequently, in such circumstances, be brought to rest over one that is warmer and specifically lighter. And this, agreeably to the fourth cause of the formation of clouds, necessarily occasions the production of clouds, by giving rise to a sinking down and intermixture of the upper with the lower atmosphere. In this way, variable winds, or rather the relative variations of temperature in neighbouring localities, and of which variable winds are merely an

indication, are frequently, though not always, instrumental in bringing about that disturbance in the calorific equilibrium of the higher and lower atmospheric currents, which occasions the formation of clouds and the falling of rain. Hence, variable winds may with greater propriety be regarded as being incidentally and indirectly accessory to the formation of clouds, rather than as the immediate causes thereof.

CHAPTER V.

ON THE CAUSES AND PRINCIPLES WHICH DETERMINE THE STRUCTURE, SUSPENSION, ELEMENTARY DIFFERENCES, AND DISSOLUTION OF CLOUDS; TOGETHER WITH A NEW HYPOTHETICAL EXPLANATION OF THE CAUSE OF THUNDER, AND THE ELECTRIZATION OF CLOUDS.

Of the Structure of Clouds.—Mists and clouds seem to consist of a multitude of hollow vesicles, or bladders, the coatings of which are inconceivably thin, and similar in structure to those usually blown from soap-suds. These vesicles vary in size, according to the measurement of de Saussure, from $\frac{1}{4222}$ to $\frac{1}{2620}$ of an English inch in diameter. M. de Saussure, senior, while travelling amongst the Alps, happened to be enveloped in a mist, the vesicles of which he described as being as large as peas. The remarkable magnitude of these vesicles compared with those seen by other observers, throws doubt upon the truth of the statement.

That clouds and mist consist of hollow vesicles, is farther proved by the circumstance of their specific gravity being such, that they remain suspended in the air without any tendency to descend, and even on frequent occasions are seen to ascend; whereas, if they consisted of round drops without any internal vacuity, their descent would be rapid. Water is 828 times heavier than air; and it has been calculated,

that a drop whose diameter is no more than $\frac{1}{1000}$th of an inch, would acquire a descending velocity of nine or ten feet per second. Besides, if clouds consisted of drops without any internal vacuity, every time the beholder looked towards them with his back to the sun, he would see a rainbow; but this is not the case except when rain is falling.

Dr Thomson, in his valuable work on Heat and Electricity, page 274, says, "But though there is no doubt that clouds consist of a congeries of vesicles, we have no conception of the way in which these vesicles are formed." Farther on in the same page, he says, "The formation of clouds seems to be connected with electricity, though in what way the vesicular form is induced by electricity, we have no conception. The vesicles seem to be all charged with the same kind of electricity. This causes them to repel each other, and of course, prevents them from uniting into drops of rain."

It does not appear to me to be a matter of much difficulty to conceive how the vesicular form should be induced by electricity, provided we can explain how they become, and how they continue electrified. We shall submit the following hypothesis by way of attempting to explain the phenomenon.

Bodies generally, if not universally, become electrified, that is, surcharged with electricity, upon being suddenly condensed. The evolution of electricity in such cases, may result either from their electrical capacity being diminished by condensation, in the same manner as their calorific capacity is thereby diminished; or it may result from a diminution in

their electric capacity consequent upon the increase of temperature which bodies acquire during condensation. This may originate in a repulsive force, which, for various reasons, I am disposed to think, subsists between caloric and electricity; so that an increase of the one, diminishes the capacity of bodies for holding the other in affinity. I am inclined to think that both these causes co-operate in producing the phenomenon in question. Now, it seems probable, that when aqueous vapour is converted into the visible form of cloud or mist, two, or likely more, particles are merely united together; and that heat and electricity, according to the principles above stated, are simultaneously evolved during the condensation which then takes place. Such is the manner in which I conceive the aqueous particles composing mists and clouds become, at their first formation, surcharged with electricity; and one reason why they continue, at least for some time, surcharged, is the circumstance of their being surrounded with air, a non-conductor of electricity.

Again, we know that the particles of electricity repel each other, and in obedience to this force, that the particles of surplus electricity distribute themselves over the surface of bodies as far separate as possible. Now, if it be admitted that electricity and aqueous vapour are mutually attractive, (of which there is no doubt,) the reason why the condensed vapour should assume the vesicular form is obvious. The particles of the surplus electricity attached externally by attraction to the particles of condensed aqueous vapour, draw it out into the vesicular form by means of their

mutual repulsion. And after it is once drawn out into the vesicular shape, and filled with air, (for it cannot be supposed that a thin film of water is impervious to air,) it is probable that it retains this form, even though the surplus electricity constituting the surcharge, may escape.*

It might be supposed that the atmospheric compression would prevent the aqueous particles from originally assuming the vesicular form. But be it recollected, that this is only one force acting against another. Without the compressing force of the external air, the mutual repulsion of the particles of surplus electricity, would distend the vesicle till it burst from the thinness of its coating. Hence the atmospheric compression may be conceived to be the cause which counteracts the mutual repulsion of the particles of surplus electricity, so as to limit the distension of the vesicles to the dimensions previously stated.

Of the Suspension of Clouds.—But then comes

* Since writing the above, I find that Dr Thomson has previously formed a similar opinion. In his work on Heat and Electricity, page 440, he says, " Air, and all gases, are non-conductors; but vapour and clouds which are composed of it, are conductors. Clouds consist of small hollow bladders of vapour, charged each with the same kind of electricity. It is this electric charge which prevents the vesicles from uniting together, and falling down in the form of rain. Even the vesicular form which the vapour assumes, is probably owing to the particles being charged with electricity. The mutual repulsion of the electric particles may be considered as sufficient, (since they are prevented from leaving the vesicle by the action of the surrounding air, and of the surrounding vesicles,) to give the vapour the vesicular form."

the inquiry, how the distension of the vesicles so diminishes their specific gravity as to cause their suspension at an elevation in the atmosphere. Upon this point, Dr Thomson, in his work on Heat and Electricity, page 274, says—" Nor is it easy to conceive why these vesicles are sometimes lighter than air, sometimes a little heavier, and sometimes exactly of the same specific gravity as the air in which they float. Indeed, if the aerial matter with which these vesicles are filled were saturated with moisture, while the air in which they float is dry, we would see a reason why they should be lighter than air. On such a supposition the clouds should rapidly disappear. Accordingly we find that, when clouds rise in the atmosphere, they speedily diminish in size, and at last vanish away; being gradually converted again into vapour. If the air within the vesicles were in the same state with respect to moisture as the air in which the cloud floats, the vesicles should be heavier than air, and constitute what we distinguish by the name of *fogs*."

Upon this quotation it may be remarked, that as aqueous vapour is specifically lighter than air nearly in the proportion of 5 to 8, it is obvious, that if the vesicles were wholly filled with aqueous vapour to the exclusion of air, which is by no means probable; or agreeably to Dr Thomson's supposition, if the air within the vesicles is more nearly saturated with moisture, than that by which they are surrounded; the less specific gravity of the aeriform matter within the vesicles might, upon aerostatic principles, compensate for the greater weight of the pellicles of water com-

posing the vesicles, and thus enable them to float at an elevation in the atmosphere, in the same manner as balloons float. After reflecting, however, upon the preceding explanation of the suspension of vesicles in the atmosphere, I am inclined to think that it is not the true one. There is reason for believing that the air by which the vesicles composing clouds are immediately surrounded, is always either saturated, or very nearly saturated, with moisture; and in rainy weather this condition of the atmosphere extends downwards to the surface of the earth. But, even in this case, clouds continue to float at an altitude of 2000 feet and upwards above the level of the sea. Now, if it be admitted that the air in rainy weather which surrounds the vesicles is saturated with humidity, the buoyancy of clouds, in such circumstances, cannot be ascribed to the air within the vesicles being more nearly saturated with humidity, than that in which they float. But Dr Thomson proceeds:

"The most probable cause of the difference of gravity between clouds and the air in which they float, is a difference in their temperature from that of the surrounding medium." After reflecting upon this point, I am inclined to think it probable, that the temperature of clouds is usually higher than that of the air at a similar altitude to that in which they float, for the following reasons. In the first place, the heat evolved during their formation should for a time produce this effect. And in the second place, after their formation, their temperature may be maintained at a greater height than that of the surrounding air, in consequence of their partially arresting and absorbing

the solar heat, in its progress towards the earth during day, and the radiation of caloric from the earth during night.

But while the temperature of clouds is usually, and probably always, higher than the air immediately surrounding them, the variations of temperature which they undergo must also be much greater than that of the atmosphere at a similar altitude. This effect may be partly attributed to the absence of the sun's heating influence during night, and the unequal obliquity with which the solar rays strike upon clouds at different periods of the day and seasons of the year; and partly to the unequal radiation of caloric from different parts of the earth's surface at different times and places. It is obvious that the aqueous vesicles composing clouds must by some means or other displace an amount of air, the weight of which is exactly equal to their own weight. If they displaced more, their specific gravity would be less than that of the air by which they were surrounded, and they would consequently ascend to a greater altitude: if they displaced less, their specific gravity would be greater than the air by which they were surrounded, and they would accordingly descend to a lower level. Now, as the vesicles composing clouds, and the aeriform matter which they contain, must be expanded, and rendered specifically lighter by every increment of temperature, it may be concluded, that their greater mean temperature than that of the air in which they float, is one of the causes of their suspension at an altitude in the atmosphere. And the greater variations of temperature which they undergo than that of the air in which they float, is

probably the principal reason why they have a tendency to rise to a greater altitude at one time, and to descend to a lower altitude at another. In warm climates, and in summer in temperate latitudes, the amount of heat arrested by clouds during its radiation towards the earth during day, and from the earth during night, must be much greater than in cold climates, or during winter in temperate latitudes. Hence the temperature of clouds should exceed that of the atmosphere at a similar altitude, in a greater degree in the former circumstances, than in the latter. And this is probably the chief cause why clouds usually float at a greater elevation in the atmosphere in warm climates, and during summer in temperate latitudes, than they do in cold climates, or during winter in temperate latitudes.

But though the variations of temperature which clouds undergo relative to that of the air by which they are immediately surrounded, may be one, and probably the principal cause which determines their tendency to ascend at one time, and descend at another; still, when the great specific gravity of water, composing the aqueous pellicle, compared to that of air (viz. 828 to 1) is considered, any superiority of temperature which the aeriform matter within the pellicle can be conceived to acquire over that of the surrounding medium, in consequence of arresting radiating caloric, seems insufficient to account, not only for the altitude at which they are usually suspended, but even for their susceptibility of suspension in the atmosphere altogether. When the smallness of the diameter of these vesicles is considered, it can-

not be admitted that the pellicle is so inconceivably thin, that its superior gravity is balanced by the inferior weight of slightly heated air within. There is, therefore, no other way of accounting for the specific lightness of these aqueous vesicles, but by supposing that they, by some means or other, prevent the aerial particles approaching so near their surfaces, as the particles of air do to each other. But how this effect is produced it is not easy to conceive.

For want of a better, we submit the following conjectural explanation :—

Water is composed of hydrogen and oxygen, the former being the strongest electro-positive, and the latter the strongest electro-negative element known. Now, upon the supposition that the two electric fluids severally distribute themselves like caloric among contiguous bodies, according to their several capacities for them, it is probable, that in consequence of the mutual attraction subsisting between the opposite electric fluids, an increased proportion of the two fluids will be concentrated by the union of two such opposite electric elements, beyond what they would severally concentrate, if existing separate, and in a state of equal density with the compound formed by their union. It is well known that an electric battery cannot be charged in a vacuum ; for, in such circumstances, the electricity escapes as fast as it is communicated. This proves that air has the power of preventing the escape of electricity ; and that this quality of air is not produced by its density enabling it to confine electricity, in the same manner as a pitcher retains water, is obvious from the fact, that the power

of air, in confining electricity, diminishes as its density decreases. The same thing is confirmed by the analogous facts of bodies being in general better conductors, in proportion as they are more dense; and of the conducting power of solids being increased by artificial condensation, such as may be effected by hammering. The only means, therefore, of explaining the reason why air prevents the escape of electricity from a body surcharged with it, is by supposing that it repels electricity. And as repulsive forces, so far as yet determined, are always mutual, it must be farther inferred that electricity exerts a repellent force towards air.

Now, if it be admitted that the union of two opposite electric elements enables them to concentrate a greater amount of the two electric fluids, than they would do if existing separately, and in a state of equal density with that of the compound formed by their union, it is by no means improbable that this additional amount of electricity so concentrated by the mutual attraction of the opposite electric fluids, repels the aerial particles most contiguous to the vesicle, in such a manner as to produce a vacuity in which no air exists close to its surface, internally, as well as externally. And hence, in this way, a hollow bladder of water, though itself greatly heavier than air, may displace an amount of air equal in weight to itself, and thus become specifically as light as the air at the altitude at which it floats.

It need hardly be remarked, that the preceding hypothesis, regarding the manner in which clouds are suspended at an altitude in the atmosphere, is entirely

conjectural, and is advanced chiefly to call attention to a meteorological fact, which has not hitherto received any satisfactory explanation.

The altitude in the atmosphere at which clouds are suspended is exceedingly various. According to Gay Lussac, their average height, in temperate latitudes, is between 4500 and 6000 feet above the level of the sea. Playfair makes it much higher. He says: "clouds occupy a region in the atmosphere, elevated at an average, between two and three miles above the earth." Indeed the altitudes of the different denominations of clouds, and even of the same denomination at different times, is so various, as hardly to admit of any mean being fixed upon. Gay Lussac's estimate is certainly, however, much nearer the truth than that of Playfair. Their medium height varies in different circumstances. For instance, it is greater in warm than in cold climates; and also greater in temperate latitudes during summer than during winter; and somewhat greater during day than during night. Their medium height is likewise greater when the barometer is high than when it is low. An inch of difference in the height of the mercury in the barometer, will make a difference in the medium height of clouds of nearly 1000 feet. The *cirri*, the most elevated of all clouds, may be estimated as floating usually at an elevation somewhere between 15,000 and 18,000 feet.* On the other hand, the lower surface of a dense *cumulo-stratus*, and of clouds generally from which rain is falling, (exclusive of mists and

* Dr Dalton conceives that the *cirri* float at an altitude varying from three to five miles above the level of the sea.

fogs which reach to the ground,) usually descends, in this country, to within 1500 or 2000 feet of the level of the sea. This is evident by observing the altitude where their lower surface, as they pass onwards with the atmospheric current, envelops hills whose height is known.

Of the Elementary Differences of Clouds.—No difference between the vesicles composing the different denominations of clouds has, so far as I am aware, been pointed out by any meteorologist. The variations, however, in the specific gravity of the different denominations of clouds, and even of different clouds belonging to the same denomination, as is demonstrated by the different altitudes in the atmosphere at which they float, shows that some difference exists.

But though the actual cause of the difference in the specific gravity of clouds has not been ascertained, it may be conceived to arise in various ways.

1. Vesicles ought to become larger and specifically lighter, as the air within them expands, from increase of temperature, such as they may be supposed to acquire by arresting a portion of the solar heat during day. And, on the contrary, they ought to contract, and become specifically heavier, as that acquired heat escapes upon the approach, and during the continuance of night. This, as we previously explained, is a reason, and probably the principal one, why clouds have a tendency to ascend, from sunrise till mid-day, and to descend upon the approach of evening. It may also, in some degree, account for the greater elevation of clouds in warm than in cold climates;

and in temperate and frigid latitudes, for their greater elevation in summer than in winter.

2. If the hypothesis which we have advanced regarding the cause of the suspension of vesicles composing clouds in the atmosphere, be correct, the more electrified they become, other things equal, the greater should be the amount of air displaced around them; and accordingly, the higher they ought to float; and *vice versa.*

3. Other things equal, (and this, exclusive of what results from difference of temperature, I conceive to be the principal cause of the original difference in the specific gravity of vesicles,) the greater the amount of water each vesicle contains, or in other words, the thicker the aqueous pellicle of which the vesicle consists, relative to its diameter, the heavier it will be, and of course the lower the altitude in the atmosphere at which it ought to float; and *vice versa.*

Judging from the fact, that the different denominations of clouds often float for a length of time, at the altitude in the atmosphere where they are formed, without any apparent tendency, (except for the variations of temperature which they undergo,) either to ascend or descend, it may be concluded that the original specific gravity of the vesicles of which they are severally composed, is determined by the density of the atmosphere where they are formed. If it be admitted, that the vesicular shape is produced by the mutual repulsion of the particles of electricity, evolved during the precipitation and conversion of invisible vapour into the visible state of mist or cloud; and if it be admitted that the atmospheric compression, is

the force which prevents the mutual repulsion of the particles of electricity, from distending the vesicles till they burst from the thinness of their coating; it is obvious, other things equal, that the distension of the vesicles, and the thinness of the pellicles of which they consist, will be greater, and their specific gravity less, according as the air is less dense at the place where they are formed. And hence the specific gravity of the vesicles composing clouds, will be less according as the altitude in the atmosphere at which they are formed is greater. Or in other words, will be proportional to the density of the atmosphere at the time and place of their formation.

Agreeably to the preceding principles it may be inferred, that the vesicles of the *cirri*, the most elevated of all clouds, should be more distended in diameter, and should consist of a thinner pellicle of water, and consequently be specifically lighter than those of any other denomination of cloud. On the contrary, the vesicles of the *stratus*, and of fogs in general, that are formed and float close to the surface of the ground, where the density of the atmosphere is greatest, should be least distended. And relative to their diameter, their pellicles should consist of a thicker film of water; and they should consequently be specifically heavier than those of any other denomination of cloud.

But the *cirri*, as well as other denominations, are frequently seen descending to a lower level, during the progressive formation of clouds, when a decrement of temperature cannot be supposed to be the cause of their descent. And, on the other hand,

clouds are frequently seen rising to a greater altitude, (and this they do usually during their dissolution by evaporation,) when an increment of temperature can hardly be supposed to be the cause of their ascent. In the former of these cases, it is not improbable, that the vesicles have their specific gravity increased, by having additional supplies of humidity precipitated on their surfaces. In the latter, it is not improbable, that in consequence of the air around them being undersaturated with moisture, their specific gravity is diminished by evaporation from their surfaces, till from their increasing thinness, they at length burst, and what remains of them becomes instantly re-converted into the state of invisible vapour.

The next phenomenon presented by clouds which we mean to consider, is the formation and dissolution of the *cumulus*. How does it come about, that small concentrated portions of the *stratus* or evening mist; or in short, that any other small fleecy clouds, visible on a fine settled summer morning, instead of dissolving, gradually congregate, and become converted, with the advancing temperature of day, into the *cumulus* or stackencloud? In what does the conversion consist? And how comes it about, that the *cumulus*, as the temperature declines upon the approach of evening, breaks up into fragments, and evaporates, after having resisted evaporation during the heat of the day, when, according to the ordinary principles by which evaporation is regulated, its dissolution by evaporation ought to have gone on with the greatest rapidity?

Agreeably to the principles previously explained, the slow ascent of concentrated portions of the evening mist after sunrise, (and a similar remark is applicable to all clouds,) is to be ascribed to the increase of temperature, and consequent diminished specific gravity, which the remaining portions of undissolved *stratus* acquire. In consequence of the solar heat radiating through the atmosphere without interruption where it is free of clouds, while it is partially arrested and absorbed by clouds, the temperature of the vesicles of which the uplifted *stratus*, and other similar fleecy clouds are composed, rises more rapidly than that of the atmosphere at an equal elevation, with the advancing heat of day. Hence the reason of their becoming specifically lighter, and expanding to a greater bulk, and rising to a greater altitude.

The circumstance of their gathering together in heaps, so as to form what is called the *cumulus*, or stackencloud, (and a similar observation may, in fact, be made of all clouds,) proves, that though the vesicles of which they are composed, be mutually repellent within a certain distance, they are mutually attractive beyond that distance. If the vesicles were mutually repellent at all distances, instead of congregating together into those masses which we call clouds, they would separate as far as possible from each other, and diffuse themselves equally throughout the atmosphere.

The phenomenon, however, which is most different from what might be expected beforehand, and which we are most puzzled to account for, is that the *cumu-*

lus seems to have little or no tendency to dissolve by evaporation, during the heat of the day, when its temperature must be greatest; and that it rapidly breaks up into fragments, and evaporates upon the approach of evening, when its temperature must have greatly diminished from what it previously was. Of these facts, no satisfactory explanation, so far as I am aware, has hitherto been given. And all we mean now to do with that intention, is to advance a hypothesis founded on the principles, that air and electricity, and caloric and electricity, are mutually repellent.

That what follows may be intelligible, it may be stated, that I conceive electricity, like caloric, is ever tending to distribute itself among contiguous bodies, according to their different capacities for it; and that electricity, when so distributed, is equally diffused among, and intermixed with, the atoms of which bodies are composed. Such is my notion of the distribution of electricity when there is no surcharge. Now, supposing one of those bodies becomes surcharged with electricity, which may be effected by heating it, the proportion of electricity which constitutes the surcharge, I conceive distributes itself over its surface. In such circumstances, if its surface be brought into contact with conductors of electricity, the surcharge instantly flies off; whereas, if it remain surrounded by non-conductors, which ought rather to be called bad conductors, it escapes only by very slow degrees. We now proceed to state our hypothesis.

That air and electricity are mutually repellent, we endeavoured in a previous part of this chapter to

prove. That caloric and electricity are likewise so, we infer from the fact, that bodies become electrified *plus*, that is, become surcharged with electricity, merely by increase of temperature ; and that the surcharge disappears as their temperature is again reduced. The consequence of this repulsion subsisting between caloric and electricity is, that as the amount of the one in any body is increased, its capacity for holding the other in affinity diminishes. According to this principle then, a cloud becomes surcharged with electricity as its temperature advances, till the hottest time of the day, and the surcharge gradually diminishes in the afternoon, as its temperature again decreases. Now, when it is considered, that the surcharge of electricity is distributed over the external surface of the vesicle, and that it repels, and is repelled by the surrounding air, it may be regarded as forming a sort of electric skin or covering to the particles of aqueous vapour composing the vesicle ; and in this way may be conceived in some degree to prevent, or retard its evaporation, that is, the intermixture and dispersion of its particles amongst those of the surrounding air. In the afternoon, however, as the temperature of the *cumulus* diminishes, and its capacity for electricity accordingly increases, the remainder of the surcharge of electricity, that is, the amount which then remains distributed externally over the surface of the vesicles, is absorbed by them. And as the cause which we supposed to be that which prevented, or at all events retarded the evaporation of the *cumulus* during the heat of the day, has then ceased to exist, its evaporation now goes on with

more or less rapidity, according as the surrounding air is more or less undersaturated. Such is the only hypothesis, imperfect though it be, which I can suggest in order to explain why the *cumulus*, as its temperature sinks upon the approach of evening, breaks up into fragments, and evaporates. Without having recourse to some such hypothesis, I do not see the possibility of explaining how the *cumulus* should continue to absorb the heat of the sun, and of course, become warmer during day, and notwithstanding show no symptoms of evaporating. And yet, when its temperature sinks after sunset, that it should rapidly evaporate. Such is contrary to the ordinary law of evaporation, viz., that moisture evaporates with greater rapidity, according as its temperature increases; and *vice versa*.

There are other circumstances which, in some slight degree, support the preceding hypothesis. But in order to understand these it may be premised, that though air be what is called a non-conductor of electricity, (and the drier it is, the better in this respect,) still there is no non-conductor so perfect, as altogether to prevent the escape of surplus electricity. Accordingly, the more rapidly the temperature of a cloud is augmented, the more certain it is to become surcharged with electricity; and on the other hand, the rise in its temperature may be so slow, that the electricity may escape as fast as it is thereby evolved. Now, it is principally in warm climates, or during the warm season of the year in temperate latitudes, when clouds exposed to the sun rapidly increase in temperature, that they assume the heaped-

up structure of the *cumulus ;* and this, in such circumstances, they always do during day. On the contrary, in cold climates, and during winter in temperate latitudes, when the heat which clouds derive from the sun is trifling in amount, and slowly communicated ; and accordingly, when the electricity evolved may be supposed to escape as fast as evolved, the clouds usually present a stratified and horizontally flattened appearance, and seldom or never that of the heaped-up structure of the *cumulus.*

In the species of cloud denominated *cumulo-stratus,* the reason of its lower portions, even during the hottest period of a summer day, presenting a flattened stratified appearance, while its upper portions consist of heaped-up *cumuli,* is to be ascribed to the circumstance of the solar heat being in a great measure obstructed, and absorbed by the heaped-up *cumuli,* which compose its upper portions. In the winter season, a similar massy cloud would assume the appearance of a dense *cirro-stratus.*

With the exception of the difference in the specific gravity and electrization of clouds, the causes of which we have endeavoured in the preceding pages to explain, there does not appear to be any distinction or difference between the vesicles which compose their various denominations. That this is the case is evident from the fact, that during the progressive formation and dissolution of clouds, and during alterations in the atmospheric temperature, such as occur in the transitions from day to night, and from night to day, clouds of one denomination may some-

times be observed to be gradually converted into every other.

Of the Dissolution of Clouds, and of Variations in the Capacity of the Air for Dissolving Moisture and Suspending Vesicles.—The dissolution of clouds is effected in two ways, viz., by falling in rain; or by evaporation and re-conversion into invisible vapour. The former of these, which we mean first to consider, is exemplified in the conversion of the *cumulo-stratus*, and also of a dense *cirro-stratus* into the *nimbus*, or rain-cloud. How does it come about that the aqueous vesicles lose their vesicular form, and descend to the earth in drops of rain? Upon this point the present state of meteorological science gives us no information, and we are accordingly again left, in forming an opinion, to the guidance of conjecture and reflection.

Judging from the slow and gradual manner in which rain descends, and also from the fact of a large proportion of the cloud continuing suspended after the rain has ceased, it may be inferred that no instantaneous or general conversion of the constitution of these clouds takes place; but that the vesicles, and only a portion thereof, individually and successively lose their vesicular form. Upon reflecting on the different degrees of rapidity with which rain falls at different times, and in different climates, I am disposed to think that the capacity of the atmosphere for suspending aqueous vesicles is limited, and varies with its temperature. And from the greater density of clouds in warm climates, as well as the greater amount of rain which falls from them in a given time, it seems probable that

the capacity of the air for suspending vesicles, like its capacity for holding moisture in invisible solution, increases with its temperature. Vesicles of a given specific gravity, upon their formation, may be supposed at a given temperature, relative to that of the air, to have a tendency to descend to, and not below, a certain altitude in the atmosphere; and owing to their mutual repulsion, a given depth of atmosphere must be loaded with them, before that degree of vesicular density and compression, in which vesicular oversaturation consists, takes place. In accordance with these views, we infer, that when any portion of the atmosphere becomes loaded with vesicles, so as to be what may be called saturated with them, any farther precipitation of moisture into the vesicular form, will cause the vesicles, or some portion of them, to approximate too near each other to remain asunder. The consequence will be, that wherever such density occurs, two or more of them will run together, just like drops of spray brought with in the sphere of each other's attraction. The united sides of the vesicles will thus become their common centre, and the attractive influence exerted by the centre, upon the external parts of the united vesicles, being proportional to the amount of water there concentrated; it seems probable, that the exterior surface of the vesicles will be drawn towards the centre where they are united; and accordingly, the vesicular form will be destroyed. The increased gravity which the integrant particle of moisture thus acquires will cause it to descend rapidly; and after destroying the vesicular constitution of, and absorbing, all vesicles with which it may have come in

contact in its fall, and perhaps after uniting with other integrant particles, which is most likely to occur in windy weather, it ultimately reaches the surface of the earth in the form of a drop of rain.

Judging from the largeness of the drops of rain, and the great quantity that falls in a short time, immediately after a thunder-storm, I am disposed to think that the previously electrified condition of the cloud, and of the air in which it floats, contributes, as well as a high temperature, in increasing the amount of moisture capable of being suspended in the vesicular form in the atmosphere. Upon this principle, the density of an electrified *nimbus* may be explained; and the successive discharges of electricity which pass from the cloud to the earth, and which are abstracted from the surrounding air, and the aqueous vesicles therein suspended, may account for the sudden and great descent of rain which succeeds, or rather concludes, a thunder-storm.

The notion that the vesicles of which clouds are composed must collapse, and fall to the earth in rain, so soon as they cease to be electrified, is indirectly disproved by the fact, that rain never falls until the clouds have acquired a considerable degree of density; and always begins to fall when they have acquired the requisite density. No reason can be assigned for a dense cloud being more apt to lose its electricity, than one that is thin and rarefied. And when it is considered that the air, though what is called a non-conductor, allows electricity to escape slowly through it from any surcharged body, it can hardly be admitted that thin rarefied clouds, which may continue to float

in the atmosphere for days, and even weeks, without producing rain, can remain all that time surcharged either with vitreous, or resinous, or with both kinds of electricity. Nevertheless, when the vesicles composing clouds are actually surcharged with electricity, (that is, contain more of one, or of both electric fluids, than they can continue to hold in affinity by means of their inherent attraction for electricity,) it is reasonable to suppose that this circumstance will increase the capacity of the air for suspending them. The mutual repulsion of the electric particles which constitutes the surcharge, will assist other causes in preventing the separate vesicles from uniting, until the vesicular density and compression, that is, the proximity and compression of the vesicles all tending towards the same horizontal altitude in the atmosphere, has become so great, as to overcome this additional repellent force.

In the same manner, the mutual repulsion of the additional particles of caloric, which the aqueous vesicles hold in affinity when the temperature of the atmosphere is increased, explains the reason why the capacity of the air for vesicles increases with its temperature.

The increasing capacity of the air for holding moisture in invisible solution, as its temperature becomes greater, admits of explanation upon the same principle. The mutual repulsion of the particles of caloric which the particles of vapour severally hold in affinity, and which increases as the atmospheric temperature rises, is probably the cause which prevents the particles of vapour uniting, as they would otherwise do, in

obedience to their mutual attraction, when they approached each other. When the atmospheric temperature rises, the number of calorific particles attached by affinity to each invisible particle of vapour may be supposed to be increased. The consequence is, that a stronger calorific repellent force now separates the particles of vapour, and greater proximity amongst them must ensue, before union and condensation into the visible form of mist or cloud can take place. And in this capability of suspending a greater number of separate aqueous particles in a given space, an increased capacity of the air for holding moisture in invisible solution consists.

According to the foregoing principles, supposing the atmosphere already saturated with vesicles, what is called drizzling rain will be produced when the air is still; and the precipitation of humidity into the vesicular form, continues to go on slowly and regularly. Every increase in the rapidity with which the precipitation of moisture into the vesicular form goes on, by correspondingly accelerating the running together of the vesicles, will augment the size of the drops of rain, and the amount that falls in a given time. During windy weather, rain can never assume the drizzling form. The agitation of the atmosphere in such circumstances, favours the uniting of the integrant particles of moisture so much, that they never can reach the surface of the earth, except in drops of considerable size.

In an undersaturated atmosphere, the dissolution of a cloud by evaporation is a gradual process, and an exact counterpart to its formation. So soon as the

aqueous film of which any vesicle is composed, becomes so thin by evaporation from its surface, that its parts are unable longer to cohere, it bursts, and may be supposed instantly to return to the state of invisible solution. And as the air at the surface of a cloud may be conceived to be more undersaturated than in its centre, the vesicles nearest its surface are the first to dissolve and disappear; and so on successively till the whole cloud vanishes from our sight.

The variations in the figure and apparent magnitude of clouds are to be ascribed, partly to their formation by precipitation going on at one place, while their dissolution by evaporation is going on at another; partly also to inequalities in the force of the atmospheric current at different portions of the cloud; and partly to the change of position relative to that of the spectator, which clouds undergo, in their onward progress with the atmospheric current.

Regarding the uses of clouds, Dr Prout says, " They are one great means by which water is transported from seas and oceans, to be deposited far inland where water otherwise would never reach. Clouds also greatly mitigate the extremes of temperature. By day they shield vegetation from the scorching influence of the solar heat; by night, the earth, wrapt in its mantle of clouds, is enabled to retain that heat which would otherwise radiate into space; and is thus protected from the opposite influence of the nocturnal cold. These benefits arising from clouds, are most felt in countries without the tropics, which are most liable to the extremes of temperature. Lastly, whether we contemplate them with respect to their form, their

colour, their numerous modifications, or, more than all, their incessant state of change: clouds prove a source of never-failing interest, and may be classed among the most beautiful objects in nature."

Of Thunder, and the Electrization of Clouds.—The only other meteorological phenomena which we mean to consider in this chapter, are those presented by a thunder-cloud. A thunder-storm is described by Dr Thomson* as follows:—

"A thunder-storm in this country commonly commences in the following manner. A low dense cloud begins to form in a part of the atmosphere that was previously clear. This cloud increases fast, but only from its upper part, and spreads into an arched form, appearing like a large heap of cotton wool. Its under surface is level, as if it rested on a smooth plane. The wind is hushed, and every thing appears preternaturally calm and still.

"Numberless small ragged clouds, like teazled flakes of cotton, soon begin to make their appearance, moving about in various directions and perpetually changing their irregular surface, appearing to increase by gradual accumulation. As they move about they approach each other, and appear to stretch out their ragged arms towards each other. They do not often come in contact; but after approaching very near each other, they evidently recede either in whole, or by bending away their ragged arms.

"During this confused motion, the whole mass of small clouds approaches the great one above it; and

* On Heat and Electricity, page 442.

when near it, the clouds of the lower mass frequently coalesce with each other before they coalesce with the upper cloud. But as frequently the upper cloud coalesces without them. Its lower surface, from being level and smooth, now becomes ragged, and its tatters stretch down towards the others, and long arms are extended towards the ground. The heavens now darken apace, the whole mass sinks down; wind rises, and frequently shifts in squalls; small clouds move swiftly in various directions; lightning darts from cloud to cloud. A spark is sometimes seen coexistent through a vast horizontal extent, of a zigzag shape, and of different brilliancy in different parts. Lightning strikes between the clouds and the earth, frequently in two places at once. A very heavy rain falls—the cloud is dissipated, or it rises high and becomes light and thin.*

"These electrical discharges obviously dissipate the electricity, the cloud condenses into water, and occasions the sudden and heavy rain which always terminates a thunder-storm. The previous motions of the clouds, which act like electrometers, indicate the electrical state of different parts of the atmosphere."

Such is the description of the phenomena presented by a thunder-storm. The inquiry which now suggests itself is, how does a cloud become electrified so as to become a thunder-cloud? Upon this point Dr Thomson† says:

"In what way these clouds come to be charged

* Robison; Supplement to third Edition of the Encyclopedia Britannica, vol. ii. page 681.

† On Heat and Electricity, page 440.

with electricity it is not easy to say. But as electricity is evolved during the act of evaporation, the probability is, that clouds are always charged with electricity, and that they owe their existence, or at least their form, to that fluid. It is very probable that when two currents of dry air are moving different ways, the friction of the two surfaces may evolve electricity. Should these currents be of different temperatures, a portion of the vapour which they always contain will be deposited ; the electricity evolved will be taken up by that vapour, and will cause it to assume the vesicular state constituting a cloud. Thus we can see in general how clouds come to be formed, and how they contain electricity. This electricity may be either vitreous or resinous according to circumstances. And it is conceivable, that by long-continued opposite currents of air, the charge accumulated in a cloud may be considerable. Now, when two clouds charged, the one with positive, and the other with negative electricity, happen to approach within a certain distance, the thickness of the coating of electricity increases on the two sides of the clouds which are nearest each other. This accumulation of thickness soon becomes so great as to overcome the pressure of the atmosphere, and a discharge takes place which occasions the flash of lightning. The noise accompanying the discharge constitutes the thunder clap, the long continuance of which partly depends upon the reverberations from neighbouring objects. It is therefore loudest, and longest, and most tremendous, in hilly countries."

The preceding explanation of the manner in which electricity accumulates in a cloud in sufficient quan-

tity to cause it to become what is called a thunder-cloud, is by no means satisfactory. To suppose that electricity is evolved by the friction of two currents of dry air moving in different directions, is unsupported by any evidence whatever, and is in some degree disproved indirectly by the following facts.

1st. Clouds are most apt to become electrified, as a previous quotation states, when "the wind is hushed, and every thing appears preternaturally calm and still." If the friction of currents of air moving in different directions caused clouds to become electrified, thunder-storms should be most frequent during windy weather. Whereas, they seldom occur, at least in this climate, except during the stillest weather we ever experience, and usually only after such has continued for a length of time.

2d. If the friction of opposite currents of air was the source whence thunder-clouds derived their electricity, thunder-storms should happen as frequently in cold as in warm climates; and in temperate latitudes as often during winter, as during summer; and as frequently during night, as during day. But the circumstance of the reverse being the fact, proves that the hypothesis under consideration is erroneous.

In what manner then does a cloud become electrified so as to become a thunder-cloud? I answer, chiefly in consequence of having its temperature rapidly augmented. Provided it be admitted that heat and electricity are mutually repellent; and that the capacity of bodies for the one diminishes as the other increases; it is obvious, that if the heat communicated by the sun to a cloud, diminish its capacity for

electricity faster than the evolved electricity escapes through the non-conducting, or rather the very slow conducting atmosphere, the cloud must become electrified, that is, surcharged with electricity, and be what is called a thunder-cloud. And it need hardly be stated, that clouds will be more rapidly heated, and of course, more speedily surcharged with electricity, according as the sun is more vertical. The causes therefore which we assigned for the conversion of fleecy flattened clouds into *cumuli*, are identical with those which electrify clouds in general. In fact, a *cumulus* is, in my opinion, an electrified cloud, though perhaps less dense, and more slightly electrified, more buoyant, and smaller in dimensions than those which usually give birth to a thunder-storm. There is likewise another difference, viz., that *cumuli*, though probably electrified themselves, usually float in an atmosphere which is not electrified; whereas, in this country at least, thunder-storms rarely occur, but when the mass of the atmosphere is in a highly electrified state.

We may submit the following facts in proof of the hypothesis above advanced, viz., that clouds, previously not electrified, become electrified, and converted into thunder-clouds, merely by increase of temperature, provided the increase be so rapid, that their capacity for electricity diminishes with sufficient rapidity beyond that with which the surplus electricity, evolved by increase of temperature, escapes through the non-conducting atmosphere.

1. Thunder-storms are of more frequent occurrence in warm than in cold climates. Indeed, in intertro-

pical climates, dense clouds, when exposed to the sun's vertical influence for any considerable time during the heat of the day, become so much heated, and of course so highly electrified, as almost always to occasion thunder. The instance given in the 3d chapter, of the clouds formed every day throughout the dry season, over the Port-Royal mountains, in the island of Jamaica, during the continuance of the sea breeze, strongly confirms the hypothesis above advanced. By one o'clock, P.M., the upper portion of those mountains, when viewed from Kingston, appears wholly enveloped in dense clouds—rain is apparently falling in torrents—frequent flashes of lightning are seen—and the sound of distant thunder is heard. That it is the heat to which the clouds are in the above case subjected, which causes their electrization, and converts them into thunder-clouds, is evident from the fact, that clouds similarly formed by atmospheric currents surmounting hills in cold climates, or during winter in temperate latitudes, never become thunder-clouds, nor occasion thunder.

2. In temperate and cold latitudes thunder-storms occur more frequently in summer than in winter. In reality, they almost never occur during winter. Now this fact, so far as it goes, confirms our hypothesis. In summer, clouds arrest a much larger proportion of solar heat in a given time than they do in winter. Hence, during the former season, they become heated, and, according to our hypothesis, electrified more rapidly, and in a greater degree, and consequently, are more apt to occasion thunder, than during the latter.

3. In our climate thunder-storms happen almost exclusively during the warmest periods of summer, and almost always between mid-day and five o'clock in the afternoon, during which period the clouds may be supposed to have acquired their greatest diurnal temperature. This, therefore, is the period of the day, when, agreeably to our hypothesis, they ought to have become most highly electrified, and be most apt to occasion thunder.

4. During our warmest weather, when the air seems to be highly electrified, and thunder-storms are going about, the thunder-like appearances which the clouds assume are most strongly marked during the warmest period of the day; and though no thunder may have occurred, those appearances gradually subside, as the temperature sinks upon the approach of evening. These facts also support our hypothesis, viz. that the augmentation of temperature which the clouds acquire by arresting the solar heat during day, is the chief cause of their electrization; and that the diminution of temperature which they undergo upon the approach of evening, by increasing their capacity for electricity, lessens the intensity of their electrified state.

5. The above hypothesis is farther confirmed by phenomena seen by a party of French philosophers from the summit of one of the Andes. Clouds which they observed descending, and which had no appearance of being electrified when near the altitude at which they were, gradually assumed the appearance of thunder-clouds as they descended to a lower level, and ultimately gave birth to a thunder-storm upon the plains beneath. In this case the clouds may be conceived

to have become electrified, partly by the increase of temperature which they acquired in their descent to a lower level, and partly by the increment of heat which they acquired by arresting the rays of an almost vertical sun.

It might be supposed, that the electricity evolved during the conversion of invisible vapour into clouds or mist, and which, in a previous part of the chapter, we represented as the cause of moisture precipitated from the atmosphere assuming the vesicular form, was sufficient to explain the electrization of clouds. But while I admit that electricity is evolved during the formation of clouds, still I conceive that the amount evolved is seldom or never sufficient, without the assistance of subsequent augmentation of temperature, to produce a thunder-storm. This opinion is confirmed by the fact, that a thunder-storm seldom or never occurs during winter in temperate or cold latitudes, be the formation of clouds ever so rapid. And, on the contrary, thunder-storms in temperate and cold latitudes usually occur during, and after a continuance of the stillest and warmest summer weather, when the clouds which give them birth are of such slow formation, as to continue hovering about, and gradually increasing in size and density, for several days before the thunder-storm occurs.

According to the hypothesis which we have now advanced to explain the phenomena of thunder, a body charged with electricity by friction, is not identical in its electric state with a cloud charged by increase of temperature. Friction produces a partial separation of the two electric fluids. The rubber and the body

rubbed severally acquire an additional amount of one of the fluids, while they lose a proportional amount of the other; and they severally gain and lose opposite kinds. Hence the one body is surcharged with negative electricity, and undercharged with positive, relative to its capacity for the several kinds; while the other body is surcharged, and undercharged, with the opposite kinds relative to its capacity; and upon this partial separation of the two electric fluids, the electric phenomena, which the bodies severally present, depend. On the other hand, when a cloud becomes electrified by means of a rapid increase of temperature, it becomes surcharged with both fluids, in consequence of its capacity for both kinds being thereby diminished. And, upon the same principle, when its temperature is rapidly reduced, it becomes undercharged with both fluids, in consequence of its capacity for both kinds being thereby increased. In the former case it gives off both kinds of electricity; in the latter it absorbs them. The reason why a cloud, or the atmosphere, attracts a body charged with one kind of electricity at one time, and repels it at another, is owing to the circumstance of bodies possessing generally, if not universally, different capacities for the different kinds of electricity; and when neither surcharged nor undercharged, containing them in unequal proportions. Now, supposing the temperature of any such body in a state of insulation to be augmented, the surcharge of electricity thereby produced will consist of a larger proportion of the one kind than of the other. Hence, in consequence of the mutual repulsion subsisting between similar electricities, it

will repel a body charged with the same kind of electricity, or a body holding in affinity a larger proportion of the same kind of electricity, with that which constitutes the largest proportion of its surcharge. On the contrary, if the temperature of the same body be rapidly reduced, so as to become undercharged, it will show the strongest electric attraction for the fluid for which it has the greatest capacity, and consequently will now attract the body which it formerly repelled. And whether electrified *plus* or *minus*, it may be expected, by means of the principle of induction, to alter or modify the electric state of any body exposed by contiguity to its influence, and to be thereby itself altered. Such I conceive is the chief reason why the atmosphere, during its diurnal and annual vicissitudes of temperature, (aided perhaps by the unequal rapidity with which its different strata are heated and cooled,) appears to be sometimes negatively, and at other times positively, electrified.

The reason why a thunder-cloud continues to give a succession of electric discharges at short intervals, may be explained as follows:—In such circumstances, the air, in consequence of an increase in its temperature, has become generally overcharged with electricity. Owing to its inferior conducting power, none but the particles nearest the ground can discharge themselves, and this they do separately, and silently. The thunder-cloud, though surrounded by the non-conducting air, is itself a conductor of electricity; and in consequence of floating in the midst of an atmosphere surcharged with electricity, after discharging itself, soon becomes again charged by the

air. The surface of the ground underneath a thunder-cloud and an electrified atmosphere, becomes, by induction, undercharged with electricity. The consequence is, that the surcharge of electricity contained in the thunder-cloud, is attracted downwards from its upper portions, and accumulated at its lower surface. This causes the under surface of the cloud to be attracted downwards towards the earth, and in consequence of greater proximity to the ground, the surcharge of electricity in the cloud becomes more concentrated at its lower surface, while its upper portions, in consequence of the descent of electricity to its lower surface, become undercharged relative to the surrounding air. Hence the upper portions are gradually attracting electricity from the atmosphere, and acting as a source whence the accumulated electricity at its lower surface is receiving additional supplies. At length a discharge of electricity from the lower surface of the cloud to the earth takes place, in consequence of the mutual repulsion of the particles of accumulated electricity becoming so great, as to overcome the insulating resistance of the non-conducting atmosphere between the cloud and the earth. After the discharge, electricity continues to be collected in the cloud from the surrounding electrified atmosphere, and gradually accumulates at its lower surface, until another discharge takes place in the same manner as above described. And thus the thunder-storm continues, until the atmosphere, by which the cloud is surrounded, is so robbed of its surplus electricity, as to be unable to supply a sufficient amount to the cloud to enable it to discharge itself.

Such is the manner in which I conceive a thunder-cloud is enabled to afford a succession of electric discharges.

Windy weather is unfavourable for the atmosphere becoming surcharged with electricity. In consequence of the aerial agitation which then exists, the different aerial strata are frequently robbed of any surcharge which they may acquire, by being brought into contact with the surface of the ground; and this happens most extensively while the atmospheric current is surmounting hills and elevated lands. Rainy weather is also unfavourable for the atmosphere becoming surcharged with electricity, partly in consequence of the rain, in its descent, carrying the surcharge to the earth along with it, and partly in consequence of a humid state of the atmosphere increasing its conducting power.

In this country, thunder-storms occur almost exclusively during the hottest period of the year, and after calm and warm weather has existed for several days, or perhaps weeks. The previous increase in the temperature of the atmosphere is one reason, why, in such circumstances, it becomes surcharged with electricity; and air being a bad conductor of electricity, the prevailing atmospheric stillness causes it to remain surcharged, with the exception of those strata near, or in immediate contact with the surface of the ground.

It may be objected to the preceding hypothesis of the atmosphere, and of clouds becoming electrified by increase of temperature, that thunder-storms sometimes happen, though rarely, during night, and during

the cold season of the year. Be it recollected, however, that during a favourable combination of circumstances, even then the temperature of the air, as well as of clouds floating therein, may be rapidly rising. For instance, we may suppose, that in consequence of the supervention of a previous very cold current of air in the upper regions of the atmosphere, the formation of clouds, and the consequent evolution of heat, according to principles previously explained, is rapidly in progress. Let it be also supposed that the lower half of the atmosphere is blowing very gently from a cold towards a warm climate, and of course gradually increasing in temperature, by communicating with a warmer and warmer surface of ground underneath. And let it be farther supposed, that the caloric previously absorbed by the surface of the earth, is now radiating therefrom with increased rapidity, in consequence of having been previously prevented from escaping at its ordinary rate, by a covering of snow, now supposed to be melted. We may easily conceive that such a combination of circumstances may increase the temperature of the air, and of clouds floating therein, so rapidly as to give birth to an electric condition of the atmosphere, even during night in the depth of winter. But the extreme rareness with which an event so unfavourable to our hypothesis occurs, proves that it is a mere exception to the general rule, arising from some very uncommon and imperfectly understood combination of circumstances. And on this account, it can hardly be admitted as an argument to disprove our hypothesis. On the other hand, the fact of thunder-storms occurring most frequently in

climates, and in seasons of the year, and in periods of the day, when, agreeably to our hypothesis, they ought to happen, together with other proofs before adduced, is strong evidence of its being true.

Thunder is more apt to occur, provided other things be equally favourable, the lower the state of the barometer is, and of course the less the altitude at which the thunder-cloud floats; but in this case, though the electric discharges may be more frequent, they are less loud. The reason of this is obvious from the analogous effects produced while charging a Leyden jar, by means of an electrifying machine. The nearer the knob of the jar is brought to the prime conductor, while the machine is in action, the smaller are the electric sparks, and the more rapid their succession. On the contrary, the greater the distance at which the sparks are drawn from the prime conductor, the larger they are, and the greater the interval between them. The greater distance of the thunder-cloud from the earth, is exactly analogous to that of the Leyden jar from the prime conductor. In both cases the electric charge requires to be stronger, in order that the repellent force of the accumulated electricity, may be sufficiently powerful to force a passage through a greater body of non-conducting intervening atmosphere.

Thunder-clouds may be too small for producing thunder. The utmost amount of electric charge which they may be able to contain, in any ordinary electric state of the atmosphere, may be insufficient to force a passage to the ground through the intervening air, from the altitude at which they float. That

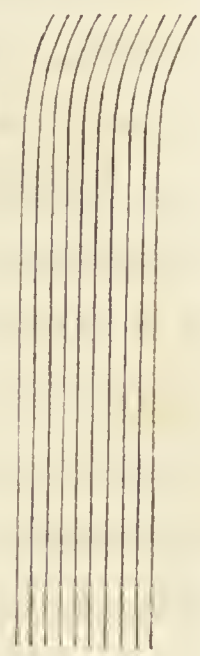
this is the fact, may be proven by the analogous instance, of the distance at which sparks can be drawn from a large Leyden jar when charged, or from a number of connected jars, being greater, than from one of small dimensions.

According to principles nearly similar to the preceding, the larger an electrified cloud is, in equally electrified states of the atmosphere, the more frequent should be the discharges from it. The reason is, a large cloud, owing to its greater extent, is more speedily re-charged with electricity than a small one, in consequence of being in contact with a greater amount of electrified air, from which it slowly and silently draws a fresh supply, to compensate for the amount it has previously discharged.

The lightning corruscations seen on warm still summer evenings passing from one cloud to another in its vicinity, are produced by one of the clouds, viz. that from which the corruscations emanate, being surcharged relative to the other. The reason why they do not remain equally charged, after the electric equilibrium may be supposed to have been established, by the passage of a flash of lightning from the one to the other, can only be explained on the supposition that the cloud which receives the electricity, is surrounded by an atmosphere, either less charged with it, or in consequence of being damper or warmer, better fitted for conducting it silently to the earth, than that which surrounds the other cloud.

The portion of a thunder-cloud, from which the lightning passes to the earth, is usually that which is nearest the earth, and which hangs down, probably

from being attracted towards it. Dr Thomson says: * "I once witnessed a thunder-storm from the summit of Lochnagar, a very high granite mountain in Aberdeenshire. The thunder was at a great distance east. The first clap was nearly due east, distant not less than ten or twelve miles. The second was north-east, and equally far off. Thick black clouds intervened between me and the thunder, so that I saw no lightning. After watching the progress of the storm for about half an hour, suddenly a white cloud of a very peculiar appearance stretched itself between the part of the heavens where the thunder was and the earth. This cloud was composed of distinct parallel fibres, bent as in the margin. This cloud continued about half an hour, during which it conveyed away all the surplus electricity from the clouds to the earth. For no more thunder was heard, and the clouds discharged themselves in a heavy shower of rain which terminated the thunder-storm."



Any person may calculate his distance from the place where an electric discharge occurs. As sound travels at the rate of 1142 feet per second, all that is necessary, is to estimate 1142 feet of distance for every second of time that elapses between the flash of lightning, and the instant at which he first hears the sound of the thunder.

When overtaken in the country by a thunder-storm, it is less safe to stand under a tree than in the open

* On Heat and Electricity, p. 444.

fields. Perhaps the safest position, in such circumstances, is about six or seven yards beyond the farthest extending branches of a large tree. The reason is, that lightning is more apt to strike a tall or elevated object, than one that is short and near the ground. For the same reason, a hollow is a safer position than an eminence. And in like manner in towns, the elevation of the buildings renders it perfectly safe to walk on the streets during a thunderstorm, beyond the distance of a foot or two from the houses. Within doors, contiguity to the walls is not so safe as the centre of the apartment. And to be in the neighbourhood of metallic substances, such as bell-wires, fenders, and grates, is more hazardous than at a little distance from them. Placed on a bed, or seated on a hair-cushioned chair, with your feet on another, in the middle of an apartment, is a position of almost perfect security, even though the lightning strikes the building, and enters the room where you happen to be. It is almost unnecessary, however, to talk of one position being safer than another. If we consider how seldom lightning injures any one of all the numerous steeples throughout the country, though severally surmounted with a metallic attractor in the shape of a weathercock; and how infinitely more likely they are to be struck than we; it will appear obvious, that even were we to select the most dangerous position which art could devise, or science point out, the chance of being hurt with lightning, during a thunder-storm, is so small, as not to be appreciable. In consequence of over-estimating the danger of being injured by lightning, I once saw a person sit back

from a dinner-table during a very moderate thunder-storm, for fear of the knives and forks attracting the electric fluid. But in such circumstances, gentle reader, even though the bell-wire be attached to the back of your chair, you need give yourself no concern about a passing thunder-storm. You run more risk of dying of disease, or in consequence of some unforeseen accident, every hour you live, than of being injured by lightning during the whole course of your existence.

CHAPTER VI.

OF RAIN, SNOW, SLEET, HAIL, DEW, HOAR-FROST, AND FALLING MIST.

Of Rain.—That the formation of clouds is a necessary antecedent to rain, is proven by the fact, that rain never falls unless the sky immediately vertical be obscured by clouds. But though clouds be essential to its production, they never produce it until they have acquired a considerable degree of density. And so soon as they are again reduced below the requisite degree of density, whether this be effected by partial dispersion, or by dissolution in the opposite forms of rain, or evaporation, the falling of rain ceases.

In the preceding chapter, when treating of the dissolution of clouds, we gave a hypothetical explanation of what we conceive takes place in the production of rain. To save recapitulation, we refer the reader to the passage alluded to. What we mean now to consider, is the difference in the amount of rain that falls at different places, and the causes thereof.

Provided other things be equally favourable, the annual amount of rain that falls, and the heaviness of the showers, are greatest at the equator, and diminish as we recede towards either pole. The reason of this is obvious, when it is considered that the aqueous capacity of the atmosphere, and evaporation, the pro-

cess by which it is supplied with humidity, increase with the warmth of the climate; and accordingly, that an equal reduction of temperature, or an equal intermixture of different portions of saturated air of different temperatures, will produce a greater precipitation of humidity from the atmosphere, in a warm, than in a cold climate. The following table, though, in consequence of local peculiarities, it exhibits slight deviations from the preceding rule, in general confirms its truth.

	N. Lat.	Inches of rain.
Uleaborg, ...	65° 30′	13·5
Petersburgh, ...	59 56	17·5
Paris, ...	48 50	19·9
London, ...	51 31	22·2
Edinburgh, ...	55 58	24·5
England, (Dalton's mean),		31·3
Rome, ...	41 54	39·0
Vera Cruz, ...	19 5	63·8
Calcutta, ...	22 25	81·0
Bombay, ...	18 57	82·0

But though the annual amount of rain be greater in warm than in cold climates, the number of rainy days, that is, days on which rain falls without reference to its quantity, is greatest in cold climates. This seems to be owing to the greater uncertainty in the direction and force of the winds as we recede farther from the torrid zone. Indeed, in all climates lying within the 30th parallel of latitude, rainy weather is for the most part restricted to particular seasons of the year; so that there are usually annual periods of four, five, six, or eight successive months, during which little or no rain falls. And even in all inland

countries beyond the 30th parallel of latitude, rainy weather is more or less restricted to particular seasons of the year; and this seems to be owing to the prevalent direction of the winds, during such periods, being unfavourable for the production of rain.

Proceeding upon the principle, that the causes which occasion rain are equal, in the course of a year, in all latitudes; and that the amount produced by those causes, is proportional to the quantity of aqueous vapour contained in the atmospheric columns in different latitudes, and which was inserted in a tabular form in our first chapter, the following table has been calculated.

Lat.	Depth of rain in inches.	Lat.	Depth of rain in inches.
0	73·17	50	25·36
5	71·39	55	21·72
10	68·72	60	18·69
15	64·47	65	16·32
20	59·11	70	14·49
25	53·12	75	13·16
30	46·77	80	12·24
35	40·58	85	11·72
40	34·92	90	11·55 *
45	29·79		

Owing to the inequalities in the amount of rain in similar latitudes, arising from local circumstances, the preceding table only gives an average approximation to the truth. It is not, however, on this account, altogether useless; for, when compared with the mean amount of rain ascertained to fall in any particular

* Hygrometry; Edinburgh Encyclopedia.

place, it may serve to determine how far that amount is affected by local circumstances.

The amount of rain observed to fall in the following places, does not deviate far from what it ought to be according to the above table.

Names of Places.	Lat.	Annual Amount of rain observed to fall.	Annual Amount per Table.
Vera Cruz, . . .	19·12	63·8	60·5
Charleston, . . .	32·40	48	43·5
Madeira, ...	32·40	35.5	43·5
Perth, in Scotland, .	56·23	21·5	21

On the other hand, in other places, the amount of rain deviates exceedingly from what it ought to be according to the table. Thus in Grenada, 105 inches have been observed to fall in a year; and at Leogane in the island of St Domingo, as much as 150 has fallen; whereas, in some parts of Peru, and in Egypt, rain is seldom or never seen.

After the lengthened explanations which we gave in the first and third chapters, of the circumstances which produce clouds, and a saturated state of the atmosphere with regard to humidity, we will here give little more than a summary of the causes which, severally and conjointly, increase or diminish the amount of rain in different localities.

In general, the nearer the sea, the more elevated the situation, and, if not on a hill, the nearer its vicinity, and the more prevalent the direction of the wind is from the sea, especially if, while coming from the sea, it blows from a southerly direction in the northern hemisphere, and from a northerly direction in the southern hemisphere, the greater is the annual

amount of rain for the latitude. On the contrary, the farther distant from the sea, and the flatter and more low-lying the country, and particularly if mountains intervene, (and the higher the better,) between the place of observation and the sea, and these be distant from the place of observation at least twenty miles, the less rain ought to fall for the latitude.

The localities where the greatest amount of rain falls for the latitude, is probably on mountains near the sea, of the height of 2000 feet and upwards in warm climates; and 1500 feet and upwards in temperate latitudes. I am not aware that the amount which falls annually in such situations, has ever been estimated by means of rain-gauges.* But that it is very great, is inferred from the fact of mountains giving birth to almost all, if not all, the large rivers in the world ; and also from the frequency with which they are enveloped in clouds, when the atmosphere at a distance from them is entirely cloudless. Thus, as before stated, in our third chapter, the summits of the Port-Royal mountains in the island of Jamaica, are enveloped in clouds, and rain there falls in torrents every forenoon even during the dry season, when in intertropical climates generally, except over, or in the vicinity of mountains, rain or clouds seldom make their appearance.

Provided mountains be 6000 feet or more in height in temperate and cold climates, and 7000 feet or more in warm climates, the rain is almost wholly precipi-

* At the Meteorological Station on the Great St Bernard, which is said to be the highest in Europe, the annual amount of rain is stated at 63.1 inches.

tated on their windward sides, and hardly any falls to leeward of them. The reason of this is, that all the denser species of clouds which produce rain in champaign low-lying countries, usually float at a lower altitude than 6000 or 7000 feet. This explains the reason why little or no rain falls in a large proportion of the kingdom of Peru, lying to the west and leeward of the Andes, whereas it rains almost incessantly on the eastern flanks of that elevated range of mountains.

If mountains, varying in height from 1200 to 3000 feet, lie immediately to the leeward of any place, or even suppose a place be entirely surrounded by such, instead of affording protection from rain, they greatly increase its amount. Thus, at Keswick, in the north of England, which lies in a hollow, surrounded almost in every direction by, and not farther distant than a mile or two from, hills varying in height from 1000 to 3000 feet, more rain falls than in any place that has yet been examined in England. The mean annual amount of rain which falls there is no less than 67.5 inches, while, at Upminster, in the flat county of Essex, unprotected by any hills, the mean annual amount is only 19.5 inches. To understand the explanation of the former of these cases, it must be recollected, that the aqueous vesicles which form clouds do not descend to the earth's surface, until their specific gravity is increased by the slow and gradual process of aggregation into what are called drops of rain. Though mountains, therefore, of moderate elevation may cause a precipitation of moisture from the atmospheric current while passing over them, still a large

proportion of that moisture is wafted by winds to a greater or less distance in the form of clouds. Now, the excess of rain in the vicinity of mountains, is partly, if not principally, owing to the influence of their elevated rugged summits, and irregular intersecting valleys, in producing a generally agitated state of the atmosphere, and a conflict of aerial currents moving in somewhat different directions. And the mechanical effect of such circumstances is, to drive together, and congregate the component vesicles of clouds into drops of rain, and thereby accelerate their descent to the earth.*

At a distance, however, of twenty miles or more to the leeward of hills of the above-mentioned moderate elevation, the amount of water precipitated among the hills, and returned to the sea by rivers, essentially contributes to the hygrometric dryness of the atmosphere, and to a diminution in the amount of rain. Before reaching this distance from the mountains, the atmospheric current has again recovered its uniform unagitated progressive movement, and, unless the formation of clouds, arising from some other cause, be going on, the remainder of the clouds formed by the mountains not previously precipitated to the earth's surface in rain, is, by this time, either dissolved, or so far in progress of dissolution by evaporation, as to be incapable of producing rain.

The following table† of the mean annual amount

* The mean amount of rain observed to fall in twenty places in the lower valleys at the base of the Alps, was 58.5 inches.

† Article England,—Edinburgh Encyclopædia.

of rain that falls in different places in England, shows the effect of local peculiarities :—

Counties Maritime.	Places.	Observed for	Mean Annual Depth.
Cumberland,	Keswick, . .	7 years,	67.5
——	Carlisle, . . .	1 year,	20.2
Westmoreland,	Kendal, . .	11 years,	59.8
——	Fellfoot, . . .	3 years,	55.7
——	Waith Sutton, .	5 years,	46.
Lancashire, .	Lancaster, . .	10 years,	45.
——	Liverpool, . .	18 years,	34.4
——	Manchester, . .	9 years,	33.
——	Townley, . .	15 years,	41.
——	Crawshawbooth, near Haslingden, .	2 years,	60.
——	Dalton, . .	1 year,	49.
Gloucestershire,	Bristol, . . .	3 years,	29.2
Somersetshire,	Bridgewater, . .	3 years,	29.3
——	Minehead, . .		31.3
Cornwall, . .	Ludguan, near Mount's bay, .	5 years,	41.
——	Another place, .	1 year,	29.9
Devonshire, .	Plymouth, . .	2 years,	46.5
——	Exeter, . .		33.2
Hampshire, .	Selbourne, . .	9 years,	37.2
——	Fyfield, . .	7 years,	25.9
Kent, . .	Dover, . . .	5 years,	37.5
Essex, . .	Upminster, . .		19.5
Norfolk, .	Norwich, . . .	13 years,	25.5
——	Dip, . . .	1 year,	25.
Yorkshire, . .	Barrowby, near Leeds,	6 years,	27.5
——	Ferrybridge, . .		26.6
——	Gars-dale, near Sedburgh, . .	3 years,	52.3
——	Sheffield, . .		33.
——	Hull, . . .	2 years,	26.98
Northumberland,	Widdrington, .	1 year,	21.2
Lincolnshire, .	Horncastle, . .	1 year,	26.
Sussex, . .	Chichester, . .		26.8
Counties Inland.			
Middlesex, .	London, . . .	7 years,	23.
Surrey, . .	S. Lambeth, . .	9 years,	22.7
——	Chertsey, . . .	1 year,	25.

Counties Inland.	Places.	Observed for	Mean Annual Depth.
Hertfordshire, .	Near Ware, . .	5 years,	25.
Huntingdonshire,	Kimbolton, . .	5 years,	25.
Derbyshire, .	Chatsworth, . .	15 years,	27.8
Rutlandshire, .	Lyndon, . . .	45 years,	22.21
Northamptonshire,	Oundle, . .	14 years,	23.
Brecon, . .		1 year,	26.25
Staffordshire, .			36.
Worcestershire,			29.
Nottinghamshire,	Nottingham, . .	1 year,	25.
——	West Bridgeford, .		27.

The following table exhibits the annual amount of rain that fell in several places in Scotland in the years 1810, 1811, and 1812:—

	1810.	1811.	1812.
Edinburgh, ...		32.26	27.1
Bothwell Castle, . .	25.0	33.1	25.0
Glasgow, ...	21.4	27.8	22.8
Greenock, ...			30.9
Largs, ...	38.7	56.6	35.2
Gordon Castle, . . .	25.9	31.3	30.8

One of the most remarkable things with regard to the different amounts of rain that fall in different places, is, that while more appears to fall at an elevation of 600 feet above the level of the sea, than at any less height underneath; the amount collected in rain-gauges below the altitude of 200 feet, increases the nearer they are placed to the surface of the ground. The following table* shows the amount of rain collected in three rain-gauges, placed at different heights, on the banks of the Tay, in the neighbourhood of Perth, in Scotland:—

* Article Scotland,—Edinburgh Encyclopædia.

	Rain-gauge on a conical hill, 600 feet above the sea.	Rain-gauge, centre of garden, 20 feet high.	Rain-gauge, Kinfaun's Castle, 129 feet above the sea.	Average of the three rain-gauges.
1814	33.84	20.05	15.59	23.61
1815	45.70	24.20	18.00	29.30
1816	52.43	24.95	19.61	32.33
1817	44.4	31.0	23.56	32.99
1818	31.10	28.07	17.89	26.35
1819	22.36	28.60	30.20	27.05
1820		23.5	18.5	21.0
1821		21.18	29.00	25.09
1822		27.80	20.22	24.01
1823		33.45	26.31	29.88

By the above table it appears, that the amount of rain collected in the rain-gauge at the top of the hill 600 feet high, was greater than at either of those placed at a lower level; but that more was in general collected in the rain-gauge at the elevation of 20 feet, than in the one at the height of 129 feet.

A more remarkable difference than the one above stated, of the amount of rain collected in gauges placed at different heights, is the following, given on the authority of Dr Heberden. The amount of rain collected in a rain-gauge, which he placed on the square part of the roof of Westminster Abbey, in the year 1776, was 12 inches; another on the top of a house considerably lower than the first, collected 18 inches; and another on the ground in the adjoining garden, collected 22 inches.

The explanation usually given of the above and similar facts, is, that the velocity of the wind on the roof of Westminster Abbey, had been greater than at either of the two points of observation underneath. And in like manner, that the wind had been stronger

at the top of the house, where the second highest rain-gauge was erected, than in the adjoining garden, where the undermost was placed. Consequently, supposing the quantity of rain that fell to be the same at the three points of observation, the quantity that would be collected on a given amount of surface, placed horizontally, in the form of a rain-gauge, should be least where the wind was strongest. As an additional reason to the one above stated, it is probable, that the rain, by bringing down a portion of the coldness which it has acquired at the altitude at which it was formed into drops, reduces the temperature of the air through which it passes in its descent to the ground. Hence the size of the drops is probably receiving augmentation the farther they descend, in consequence of aqueous precipitation, produced by the coldness communicated to the aerial strata through which they pass in their descent. This is supposed to be farther increased, by the condensation of moisture evaporated from the earth's surface, during the continuance of rain.

From the table inserted above it will also be seen, that the amount of rain which falls at the same place in different years, is very different. A similar remark is applicable to the corresponding months of different years, as the under-noted statement shows.

Rain collected at Barlanerk.	Rain-gauge.
In October, 1831, . . .	5 inches 7-10ths.
In October, 1830, . . .	1 inch 4-10ths.
From 8th to 31st October, 1829,	2 inches 3-10ths.

Such differences are to be ascribed partly, if not wholly, to the different direction and velocity of the

winds in different years, and in the corresponding months of different years. Thus at Glasgow, if the prevailing direction of the wind be from the south or south-west, (and the stronger it blows the greater the effect,) during the months of December, January, and February, the amount of rain will be immensely greater than if the prevailing direction had been from the opposite quarter.

The annual amount of rain that falls near the western coast of Britain, is in general greater than what falls near the eastern coast. This is owing to the circumstance of air becoming usually hygrometrically drier the farther it passes overland, in connection with the fact of winds from the south-west being more prevalent in this island, than winds from the south-east.

Nor is a wind blowing from the sea towards the land necessarily a rainy wind, provided the land be warmer than the sea from which it blows. In such circumstances, as the atmosphere progresses over the land, it gradually becomes warmer and more under-saturated, and accordingly less apt to give birth to clouds and rain. This is the reason why it almost never rains in Egypt, though the wind during a large proportion of the year blows from the Mediterranean. The aqueous vapour raised from that inland sea, is carried with a northerly wind unprecipitated, till it comes into collision with the elevated mountains in the kingdom of Abyssinia.

The following Meteorological Register, with the accompanying note of attestation, is copied from the Glasgow Chronicle.

METEOROLOGICAL REGISTER KEPT AT ANDERSON'S UNIVERSITY, 1833.

	Rain.			Thermometer.			Self-registering Thermometer.		
	Day.	Night.	Total.	Morn.	Night.	Mean.	Cold.	Heat.	Mean.
January, .	.11	.12	.23	34.9	35.1	35.	31.3	38.1	34.7
February,	1.23	2.21	3.44	42.4	41.	41.7	37.4	43.4	40.4
March, .	.20	.36	.56	41.	38.6	39.8	36.	44.7	40.4
April, . .	1.18	.44	1.62	48.1	43.9	46.	41.2	52.5	46.8
May, . .	.15	.81	.96	60.	55.2	57.6	66.1	49.1	57.6
June, . .	1.99	1.44	3.43	59.4	55.	57.2	51.4	65.	58.2
July, . .	.69	.62	1.31	63.3	58.2	60.7	53.7	68.3	61.
August, .	.54	.77	1.31	59.5	55.4	57.5	50.1	63.8	57.
September,	.78	.79	1.57	56.6	53.3	54.9	49.3	60.8	55.1
October, .	1.47	1.52	2.99	51.	49.	50.	45.6	54.4	50.
November,	1.25	1.02	2.27	43.9	43.3	43.6	39.3	46.9	43.1
December,	3.07	3.56	6.63	42.	40.6	41.3	38.6	42.7	40.6
Total, .	12.66	13.66	26.32	50.2	47.4	48.8	45.	52.4	48.7

"I inclose you the results of the Meteorological Register kept in this Institution for 1833, in as far as regards the quantity of rain and the temperature. The observations are made with great care and accuracy by Mr Johnston, keeper of the Museum, and registered twice a-day, viz. at half-past nine A. M. and at half-past nine P. M. The register exhibits the quantity of rain fallen during the day, which amounts to 12.66 inches, and during the night to 13.66; together, $26\frac{1}{3}$ inches. The mean heat of the year by the morning observations, is 50.2, and by the evening ones, 47.4; the mean of both is 48.8. The mean of the greatest cold of each day is 45, and of the greatest heat 52.4, exhibiting a range of 7.4. The mean of the self-registering thermometer is 48.7,

agreeing with the other series of thermometrical observations to the tenth part of a degree.

James Smith,
President, Anderson's University."

From the above table it appears that the amount of rain which falls during the days throughout the year, from half-past nine A. M. to half-past nine P. M., is greater by about $\frac{1}{12}$ than what falls during the nights throughout the year, from half-past nine P. M. to half-past nine A. M. This may be explained on the principle, that the reduction of temperature which takes place during night, increases the precipitation from the atmosphere.

The following register of rain also for 1833, was kept by Dr Couper, at the Macfarlane Observatory:—

January . .	0.256
February . .	2.609
March . .	0.598
April . .	1.072
May . .	0.778
June . .	2.617
July . .	1.082
August . .	0.936
September . .	1.018
October . .	1.987
November . .	1.753
December . .	5.202
	19.908

It will be observed that the above table differs con-

siderably from the one previously inserted, though the places where the observations were made are only about one mile distant from each other. This discrepancy may be ascribed, partly to differences in the amount of rain that falls in neighbouring localities, and partly to inaccuracy in keeping the registers. The latter register must be regarded as being the most accurate, having been kept by a scientific individual, while the former was not.

By the above table, as well as by other observations, it appears that the amount of rain during the fall, is usually greater than during the spring of the year. Thus, in the months of September, October, and November, the amount of rain as given above, is greater than in the opposite months of March, April, and May. The reason of this is, that, during the former of these periods, (viz., the fall of the year,) the temperature and capacity of the atmosphere for moisture is diminishing ; whereas, during the latter, (viz., spring,) the temperature and capacity of the atmosphere for moisture is increasing.

The following statements are extracted from Cleland's Annals of Glasgow :—

" The average of rain which has fallen in Glasgow for 30 years, previous to 1790, is $29\frac{65}{100}$ inches.*

* By all the meteorological registers kept for many years past, the annual amount of rain which has fallen at Glasgow is little more than two-thirds of the mean stated above in the text. Glasgow, from its low-lying position, and from its being surrounded by hills of moderate elevation in every direction, and being at the same time at a considerable distance from any hills, is situated in a dry locality for the latitude. The annual amount of rain at

The greatest quantity in any year, during that period, was in 1775, which was $43\frac{9}{100}$ inches, and the least, which was in the year 1788, was $19\frac{47}{100}$ inches.

" *The Quantity of Rain that has fallen annually in Glasgow, during the following years, in inches and decimal parts :—*

1765 . .	24.77
1775 . .	43.9
1785 . .	27.19
1795 . .	36.064
1805 . .	15.382

" 1815.—*The following is a Statement of the Rain collected in Gauges, made by the celebrated Crichton of Glasgow :—*

	Bothwell.	Glasgow.	Carbeth.	Greenock.
January .	0.886	1.135	0.750	0.809
February .	2.276	2.312	4.855	3.928
March .	2.883	2.457	5.563	5.485
April .	0.783	0.925	1.430	1.267
May .	2.765	2.104	3.684	3.128
June .	1.586	1.246	1.831	1.820
July .	2.040	1.531	1.711	1.235
August .	2.600	2.354	3.638	2.647
September .	2.328	2.275	5.552	4.077
October .	3.280	2.402	5.308	5.785
November .	1.908	1.823	3.869	3.700
December .	1.385	1.780	3.202	2.882
	24.720	22.344	41.393	36.763

Glasgow, must therefore have either diminished to little more than two-thirds of what it was half a century ago ; or, which is more probable, the registers referred to by Dr Cleland in the text, must have been inaccurately kept.

"Bothwell Castle is about 7 miles S.E. of Glasgow. Carbeth, 11 miles N.N.W. of Glasgow. Greenock, 22 miles W. of Glasgow."

As the aggregate amount of heat which the earth annually receives from the sun, and the amount of moisture annually evaporated from the earth's surface, probably undergo little or no variation; the aggregate amount of rain which falls on the earth's surface, must in like manner be similar every year. Hence, in conformity with this principle, it may be inferred, that wetter seasons than ordinary in one country, or climate, are simultaneously balanced by seasons proportionally drier than ordinary, in some other country, or climate. Such differences are wholly to be ascribed to variations in the direction and force of the winds in different seasons. And it is farther probable, that the differences in the prevailing direction and force of the winds, are also regulated according to some compensating principles, by which different countries within a limited number of years, are supplied with their relative mean proportions of rain.

It is recorded upon authentic evidence, that rain sometimes of a yellow, and sometimes of a red colour, has on rare occasions been observed to fall in various places. In these cases, the colouring matter appears to have been derived from vegetable pollen of the colours described, transported by winds, and precipitated to the earth, along with showers of rain. Snow of a red colour has also been observed in Iceland. The colouring matter in this case was imputed to a mixture of red ashes, ejected during a vol-

canic eruption in the neighbourhood. It is also said to be recorded upon authentic evidence, that, during a strong gale of wind, herrings and other fish were carried from the Frith of Forth, as far as Loch Leven. It is likewise on record, that a shower of rats once fell in Norway ; and also, that a shower of toads fell near Porto-Bello, lying to the east of Edinburgh.

That vegetable pollen, one of the lightest and most transportable of all substances, should be carried by wind, and precipitated to the earth by a shower of rain, is by no means unlikely. But that herrings and other fish should be blown out of the Frith of Forth, and transported twelve miles over land, by means of a strong gale of wind, even though recorded on what is called authentic evidence, is a very improbable circumstance. And how it came to pass, that any species of wind whatever, even a whirlwind, should have selected rats on one occasion, and toads on another, for atmospheric transportation, and nothing else, may be left to posterity to discover.

Of Snow.—When the atmospheric temperature at which clouds begin to lose their vesicular constitution is below the freezing point, the aqueous particles are congealed; and provided the atmospheric temperature continues below the freezing point down to the surface of the earth, the frozen particles most contiguous to each other, after uniting together while descending, into various crystalline symmetrical arrangements, ultimately reach the earth in the form of flakes of snow. The precipitation of moisture into the form of snow, is frequently exemplified on a small scale, in high latitudes, by the admission of a current

of the external air much below the freezing point, into a heated apartment loaded with aqueous vapour. Dr Robertson states, that, in a crowded assembly-room at St Petersburgh, a stream of cold air was accidentally admitted into the room by a gentleman breaking a pane of glass, on which the vapour in the air was immediately congealed, and fell in the form of snow flakes.

Within the torrid zone, snow is never seen except on elevated mountains. The reason is, that at all low altitudes the atmospheric temperature, in that region of the earth, is always greatly above the freezing point. For a similar reason in temperate latitudes, the falling of snow is restricted to the colder season of the year. But in the polar regions, almost the whole moisture precipitated from the atmosphere during all seasons of the year, descends to the earth in this form.

Snow is characterized by the whiteness of its colour, and by the spongy lightness of its texture. The former of these qualities, viz., its whiteness, is peculiarly useful for reflecting and increasing the amount of light, in those dark and dreary regions where it is constantly to be found. In those climates, even the light of the stars, or of the aurora borealis, when assisted by the reflection of snow, is sufficient in the absence of the sun and moon, to enable the traveller to direct his journey with perfect ease and safety.

The light spongy texture of snow, by diminishing its power in conducting heat, renders it extremely useful in protecting the more tender herbs and plants from destruction, during the frigid season of the year.

And though in our temperate climate, we are in the habit of regarding snow as the emblem of winter and coldness, the qualities above-mentioned, have pointed it out to the natives of polar latitudes, as a fit substance wherewith to construct their huts, in order to protect themselves against the rigorous frost of an arctic winter. Besides these useful purposes, the gradual melting of the immense quantities of snow deposited in Alpine regions during winter, affords a regular and constant supply of water to many rivers on the continent, which would otherwise become unnavigable during the heat and drought of summer.

Of Sleet.—When it is considered that the temperature of the atmosphere decreases at the mean rate of one degree of Fahrenheit for every 300 feet of perpendicular ascent, it may be easily conceived, that the atmospheric temperature at a considerable altitude may be below the freezing point, while at, and near the earth's surface, it is above it. In this case, precipitated moisture descending in the frozen form of flakes of snow, begins to melt so soon as it reaches those atmospheric strata, the temperature of which is above the freezing point. In such circumstances, the snow, by the time it reaches the surface of the earth, is partially melted ; and has received the name of sleet.

Of Hail.—Hail appears to be descending moisture frozen, after being formed into drops of rain of greater or less magnitude.

One of the difficulties which has puzzled meteorologists to solve, is how it gets frozen in descending to a lower altitude, while at a higher altitude, the parti-

cles of precipitated moisture should have time to unite together in the course of their descent, so as to form drops of rain before being frozen. If the temperature of the higher region, like those underneath, be under the freezing point, the aqueous vapour, so soon as condensed into particles of the smallest size, would congeal, and afterwards could only unite and aggregate into the form of snow. And once formed into snow, could not possibly assume the form of hail, without being first melted into drops of rain, and thereafter frozen. It is obvious, therefore, that the atmospheric strata at the higher altitude, contrary to the principle of the aerial temperature decreasing upon ascending perpendicularly, must have been warmer than those underneath, and this is the point which meteorologists are puzzled to explain.

The difficulty under consideration may be obviated in two ways, both of which probably in different circumstances occur. First, supposing the precipitation of moisture from the atmosphere at a great altitude to be rapidly going on, the heat thereby evolved may be sufficient to raise the temperature of the aerial strata, where the aqueous precipitation is in progress, above the freezing point; while the atmospheric temperature for a considerable distance underneath, which has not participated in this adventitious accession of warmth, may be considerably below the freezing point. In such circumstances, the aqueous particles, before reaching the cold aerial strata underneath, may be so far enlarged by uniting together, as to form drops of rain; and which, upon being frozen during their subsequent descent through the colder aerial strata, be-

come hailstones. Second, provided the opinion advanced in the preceding chapter be correct, viz. that an electric state of the atmosphere increases its capacity for holding moisture, not only in invisible solution, but also in the visible form of cloud, it is probable, that in those electric states of the atmosphere, when hail accompanies, or rather terminates, a thunder-storm, the amount of moisture which, in consequence of the abstraction of electricity, is instantly precipitated, may be so great, as to form drops of rain of moderate size. And provided such takes place at an altitude where the temperature is below 32°, hail, instead of drops of rain, will instantly be formed.

Hail is chiefly restricted to the temperate latitudes of the earth, and in these is most frequent during spring and summer. Within the tropics, it seldom falls at a lower altitude than from 1500 to 2000 feet above the level of the sea. The explanation usually given of this fact is, that the atmospheric temperature which increases downwards to the surface of the earth, is constantly so high in those regions, that hail never descends to a lower altitude than that above mentioned, without being melted.

Hail also seldom or never falls in any latitude much above 60°. The reason of this is, that in high latitudes the amount of aqueous vapour precipitated from the atmosphere is so small, as to be incapable of raising the temperature of the aerial strata where it is precipitated, sensibly above that of those underneath. And if the atmospheric temperature where precipitation of humidity is going on, or where the vesicles are losing their vesicular form, and all underneath, be

under 32°, the aqueous particles, when only of their first and smallest size, will be severally frozen as they are precipitated; and, as before stated, the only union which they can thereafter adopt, without being again melted, is that which they usually exhibit in the form of a flake of snow. For a similar reason to the preceding, hail seldom falls in temperate latitudes during winter.

In this country hail-storms seldom assume any remarkable appearance. But in some other countries, especially in the southern districts of France, between the Alps and the Pyrenees, hail-storms are so violent, and the hailstones so large, as frequently to lay waste large districts of country. They are usually accompanied with thunder, and a violent squall or whirlwind. On such occasions, individual hailstones have been found to weigh as much as five ounces, and sometimes more; and, instead of presenting the usual globular form, appear to be irregularly shaped angular masses of ice.

It is observed that those remarkable hail-storms which are accompanied with thunder usually occur in the warmest period of the year, and very seldom during night or winter. The same thing, however, may be said regarding thunder-storms accompanied only by rain. It is therefore presumable, that the hail is a mere accompaniment to the thunder-storm, and more or less dependent upon, or produced by it. Hence the reason which we formerly assigned for thunder-storms occurring most frequently during the warmest period of the day, and of the year, is equally applicable to hail-storms which accompany thunder.

The immense magnitude of the hailstones in such storms, and the intensity of cold during the hottest period of summer, requisite to freeze them in their descent to the earth, has never been satisfactorily accounted for. The only explanation offered is, that they must have been originally formed at an altitude in the atmosphere, where the temperature is greatly below 32°, and in consequence of their extreme coldness, that they acquired magnitude during their descent, by condensing on their respective surfaces, the copious vapours contained in the electrified cloud and atmosphere through which they passed. The difficulty, however, is not altogether obviated by this conjectural explanation. For supposing the atmospheric temperature at the surface of the earth, immediately previous to one of those hail-storms, to be at 72° of Fah., (and which is only a moderate temperature for the southern districts of France, during the hottest period of the year, when such storms usually happen,) it would require an elevation of 9000 feet, at the mean decrement of one degree for every 300 feet of ascent, before the freezing temperature of 32° was attained. And supposing the atmospheric temperature at the earth's surface to be at 82°, it would require an elevation of 12,000 feet before the freezing temperature was reached. Now, when it is considered that the medium height of clouds, according to Gay Lussac, is between 4500 and 6000 feet, it looks like stretching conjecture beyond admissible probability, to suppose that the thunder-cloud extended to an altitude much beyond 9000 feet in the one case, and much beyond 12,000 feet in the other, so that the hailstones at their

first formation may have acquired such an intense degree of coldness, as to be able, during their descent, to congeal on their surfaces an amount of vapour sufficient to account for their immense magnitude, by the time they reach the ground. In such cases, it is usual both for the learned and the ignorant to get quit of the difficulty, by ascribing it to electricity. But this is merely an evasion, and not a solution of the question, unless it can be shown that water can be frozen by means of electricity, at a lower temperature than 32°.

The simplest and the most plausible way of explaining the phenomenon, is to suppose that the thunder-cloud is floating at an altitude where the temperature of the atmosphere is below the freezing point; and that the mass of aqueous vapour concentrated and suspended in the vesicular form, is, in consequence of electrization, so great, that the collapsing and uniting of the vesicles, upon the escape of the electric fluid in the form of lightning, at once produces hailstones of the magnitude described. By this means we get rid of the difficulty of supposing, that the *nuclei* of the hail-stones are formed at an altitude sufficient to account for the acquisition of such a degree of coldness, as to enable them to acquire the magnitude described, by congealing on their surfaces the aqueous vapours through which they pass in their descent to the earth.

The squall of wind, or whirlwind, which accompanies and ushers in the hail-storm, is no doubt produced by the depression of temperature which the hail communicates to the lower atmosphere, in its

descent to the ground. The explanation of this fact is analogous to that given in the fourth chapter, regarding the influence of a shower of rain in warm climates, in producing sudden gusts, and sometimes a change in the direction of the wind. That explanation we need not here repeat.

On the supposition that hail-storms were occasioned by an unequal distribution and accumulation of electricity in the atmosphere, it was proposed by certain French philosophers to draw off the electric fluid by means of lightning-rods, similar to those erected for the protection of buildings; and it is said that where these have been introduced, they have had the desired effect. I am not aware upon what extent of experience the supposed beneficial effect of these hail-rods is founded. But when it is considered that the hailstones in question must have been formed at an immense altitude, and that air is a non-conductor of electricity, and consequently, that a hail-rod can only affect the electrical condition of a very limited amount of air in its immediate vicinity; it is probable, that their influence in affording protection against hail and thunder-storms, may have been somewhat over-estimated. At a random guess, I am inclined to think, that a large tree, 80 feet high, would have as much influence, by means of its numerous pointed branches, in robbing the atmospheric current of its surplus electricity, as a single hail-rod 40 feet in height. There is no doubt, however, that lightning-rods, if sufficiently numerous and sufficiently elevated, which last can be best accomplished by erecting them along the summits of hills and rising grounds, would

in some degree assist in maintaining an electric equilibrium between the atmosphere and the subjacent earth; and consequently, that they would have a corresponding influence in diminishing the frequency, and mitigating the violence of such storms.

Of Dew and Hoar-frost.—When treating of the formation of the *stratus* or fall-cloud, in our third chapter, we explained the causes and principles which, according to the experiments of Dr Wells, determine the formation of dew. To these, therefore, we refer, and if more information be wanted, illustrations sufficiently copious will be found in Dr Wells's Essay on Dew. We shall only here briefly mention, that dew consists of moisture precipitated from the aerial strata nearest the ground, in consequence of coldness induced by radiation of caloric from the earth's surface, during calm clear nights, being communicated to those strata in sufficient intensity to produce oversaturation.

In consequence of dew resulting from the depression of temperature arising from radiation, it falls most copiously in those places where the surface of the ground is best fitted for radiating caloric. Hence, agreeably to the beneficent designs of Providence, by which scarcity produces proportionate economy, and by which all phenomena are adapted upon the wisest principles to serve useful purposes, frugality in its distribution is observed to be proportionate to the smallness of its quantity. Thus, when the air is dry, and the quantity of dew that falls during night is very limited in amount; in accordance with the principles which regulate the degree of coldness induced by radiation on different parts of the earth's surface, the

deposition of dew seems as if it were reserved for those vegetable productions, which stand most in need of its moistening influence, and of the heat evolved during its deposition, to protect them from the coldness by which it is produced. "This fluid," says Dr Wells, "appears chiefly where it is most wanted, on herbage and low plants, avoiding, in great measure, rocks, bare earth, and considerable masses of water. Its production too, by another wise arrangement, tends to prevent the injury that might arise from its own cause; since the precipitation of water, upon the tender parts of plants, must lessen the cold in them, which occasions it."

Hoar-frost is merely frozen dew. The great evolution of heat which attends the conversion of dew into hoar-frost, is another wise arrangement by which the coldness is farther mitigated; and those herbs and plants upon which dew is deposited, are farther protected from the extreme depression of temperature to which they would otherwise be subjected.

The quantity of moisture that falls in the form of dew, averaged for the whole of Great Britain, has been estimated by Dr Dalton at five inches, and by Dr Thomson, at four inches annually. I am not aware upon what principle the estimate is made. But when it is considered, that dew only falls during night; and only when the nights are calm, and cloudless; and that the number of such nights throughout the year, in our windy climate, is very limited. And when it is farther considered, that little or none falls on hills, or other acclivities; nor on trees, or the ground which they shelter; and little or none on

rocks or roads. And, in short, when it is considered, that the falling of dew is chiefly restricted to hollows and plains, consisting of grass fields, or uncovered ploughed lands; and particularly when the smallness of the amount that falls in any night, is compared with what falls of rain in a similar time, and which is not limited to particular localities, nor to any proportion of the day or night, it seems probable, that five inches of dew annually, which is equal to $\frac{1}{6}$th part of all the moisture that falls in the different forms of rain, snow, and hail, is double, or perhaps triple its actual amount.

Of Falling Mist.—Falling mist is the only aqueous deposition which remains to be noticed. It commonly occurs in still weather, and, in our climate, makes its appearance most frequently during the winter season, when the temperature is either below, or little above the freezing point. In the former case, after having fallen, it has the same appearance as hoar-frost; in the latter, it resembles dew. Most frequently it results from the same cause as dew, viz., from the reduction of temperature, induced upon the earth's surface by calorific radiation, being propagated upwards through the atmosphere in sufficient intensity to produce aerial oversaturation. Frequently this cause is assisted by a gradual sinking of the temperature of the atmosphere generally. In some countries, such as in a portion of Peru, almost the whole moisture which the soil receives to support vegetation, is supplied from falling mist and dew. In others, such as Egypt, these are assisted by periodic river inundations. The amount of moisture supplied

to the soil by falling mist, is, in some places, very considerable. "In that part of Peru," says Dr Thomson, "called Valles, which lies on the north and south side of Lima, in south latitude 12°, bounded on the east by the Andes, and on the west by the Pacific ocean, it never rains at all. But, during winter, the earth is covered with so thick a fog as to intercept the rays of the sun. This fog appears almost every day during winter, with a density that obscures objects at any distance. About 10 or 11 o'clock it begins to rise, but without being totally dispersed; though it is then no impediment to the sight, intercepting only the direct rays of the sun by day, and that of the stars by night. Sometimes it is so far dispersed that the disc of the sun becomes visible, but the heat from his rays is still precluded. In the winter, these vapours dissolve into a very small mist or dew, which they call *garua*, and thus every where moistens the earth. These *garuas* never fall in quantities sufficient to damage the road, or incommode the traveller; but they render the most arid and barren parts fertile. They convert the disagreeable dust in the streets of Lima into mud."

What is called an eastern *haar* on the east coast of Britain, is also a falling mist, accompanied with an east, or north-east wind. When its density becomes considerable, it moistens the clothes of a person exposed to it; and this it does more readily, and with a less degree of density, if he be going against the wind. It is usually occasioned by the gradual condensation of the moisture evaporated from the sea,

when its surface is warmer than the incumbent atmosphere.

We will only farther observe, that a falling mist may occur in any circumstances, when the lower atmosphere undergoes a reduction of temperature, after it has reached the point of saturation. In such circumstances, it may be considered the slightest degree, and frequently forms the commencement of drizzling rain. The case narrated in the third chapter of the gradual conversion of floating, into falling mist; and of falling mist into drizzling rain, upon ascending the upper portion of Goatfell in the island of Arran, affords a striking exemplification of the point under consideration. It was there stated, that the ground was quite dry, and the mist produced no visible deposition of moisture upon our clothes, lower than about 300 feet perpendicular from the top. At that elevation, however, the ground assumed the appearance of dampness; and moisture, at first in such small quantity as to be almost imperceptible, began to be deposited upon our clothes. In our farther ascent, this condition of the atmosphere gradually increased, so that at the summit of the mountain, we found ourselves surrounded with an exceedingly dense mist, attended with drizzling rain.

CHAPTER VII.

ON THE CAUSES AND PRINCIPLES WHICH REGULATE AND DETERMINE THE VARIATIONS OF TEMPERATURE ON THE EARTH'S SURFACE.

Of the mean temperature as affected by difference of latitude, both by sea and land.—The greater or less mean temperature of the earth in any latitude, obviously results from the different degrees of obliquity with which the sun's rays fall upon its surface, during its diurnal revolution on its axis from west to east. It is accordingly found, that the mean annual temperature decreases as we recede from the equator towards either pole. If the plane of the ecliptic corresponded with that of the equator, the mean diurnal temperature of the earth in each latitude, would undergo no variation throughout the year. Owing, however, to the deviation of the plane of the ecliptic from that of the equator, and consequently to the sun's gradual declination from the equator towards the north to the extent of 23½ degrees, during our summer; and towards the south to a similar extent, during our winter; corresponding latitudes in the opposite hemispheres of the earth, are periodically and simultaneously undergoing opposite variations of temperature from the mean for the latitude. And the extent of these variations, except what arises from

circumstances hereafter to be noticed, is proportional to the greater or less obliquity of the sun's rays, and the variations in the length of the day in different latitudes, and different seasons of the year.

Though the mean annual temperature for any given latitude be nearly the same, whether it be land or water, the extreme temperatures of summer and winter are very much influenced thereby. In summer, the surface of the sea is much colder than that of the land at a distance from the sea in the same latitude; whereas, in winter it is much warmer. The mean annual range of temperature of the surface of the Atlantic, for the temperate zone, is only about 9°, and that of the torrid zone is not above 4°; whereas, the annual range of temperature for inland continental countries in temperate latitudes, exceeds 100°. In like manner, in the equatorial regions, the extreme atmospheric temperatures of day and night, over the ocean, never exceed three or four degrees; while upon land, the difference often amounts to 9° or 10°. Between the 25th and 50th parallels of latitude, the extremes in the diurnal range of temperature at sea is only from 4° to 5°; while at Paris it often amounts to 20° or 30°. This great difference in the annual and diurnal range of temperature between land and ocean, is partly to be ascribed to the greater calorific capacity of the latter; and partly to its power of preserving uniformity of temperature, by increased evaporation during the heat of day, and by the sinking down, agreeably to statical principles, of the upper particles, as they become colder and heavier than those below, during night.

Within the tropics, the mean temperature of the ocean is generally higher than that of the air in contact with it. This is chiefly owing to the greater mobility of the atmosphere, and consequently, to a larger proportion of the solar heat being transferred to colder latitudes by currents in the atmosphere, than by currents in the ocean.

In the temperate zones, the mean diurnal temperature of the ocean is a little lower in summer, and a little higher in winter, than the mean diurnal temperature of the incumbent air in the same parallel. This is owing to the greater heat of the land in corresponding latitudes during summer, and its greater coldness in winter, being more freely communicated to the atmosphere over the ocean by aerial currents, than to the subjacent water.

Of the time when the maximum, minimum, and mean annual temperatures occur in the atmosphere, and also at different depths below the surface of the ground.—In temperate latitudes, such as from 35° to 55°, the greatest annual temperature of the atmosphere, occurs from about a fortnight to three weeks after the summer solstice ; and its lowest annual temperature, about a similar length of time after the winter solstice. In like manner, the mean annual temperature of the atmosphere is attained, in spring and autumn, from two to three weeks after the vernal and autumnal equinoxes respectively. Nearer the equator than the 35th parallel of latitude, the maximum temperature of summer, and the minimum of winter, will occur earlier after the solstices ; and beyond the 55th parallel of latitude, somewhat later, than the time above stated. This is owing to the greater annual range of tempera-

ture on receding from the equator towards either pole; and consequently, to the increasing amount of heat which the earth has to absorb during summer, and give out during winter, before attaining its maximum and minimum temperatures.

The farther we dig down below the surface of the ground, the maximum temperature of summer, and the minimum of winter, are longer after the summer and winter solstices of being attained. And the annual range of temperature gradually becomes less, from the surface downwards, to the depth of between forty and fifty feet, where the temperature remains unaltered throughout the year. The following table* exhibits a statement of the mean temperature of the earth at the depth of one, two, four, and eight feet, below the surface of the ground, for each month in the years 1816 and 1817.

	1816.				1817.			
	1 foot.	2 feet.	4 feet.	8 feet.	1 foot.	2 feet.	4 feet.	8 feet.
January, .	33.8	36.3	40.7	43.0	35.6	38.7	40.5	45.1
February,	33.7	36.0	39.0	42.0	37.0	40.0	41.6	42.7
March, .	35.0	36.7	39.6	42.3	39.4	40.2	41.7	42.5
April, . .	39.7	38.4	41.4	43.8	45.0	42.4	42.6	42.6
May, . .	44.0	43.3	43.4	44.0	46.8	44.7	44.6	44.2
June, . .	51.6	50.0	47.1	45.8	51.1	49.4	47.6	47.8
July, . .	54.0	52.5	50.4	47.7	55.2	55.0	51.4	49.6
August, .	50.0	52.5	50.6	49.4	53.4	53.9	52.0	50.0
September,	51.6	51.3	51.8	50.0	53.0	52.7	52.0	50.7
October, .	47.0	49.3	49.7	49.6	45.7	49.4	49.4	49.8
November,	40.8	43.8	46.3	45.6	41.0	44.7	47.0	47.6
December,	35.7	40.0	43.0	46.0	37.9	40.8	44.9	46.4
Mean of whole year, . .	43.8	44.1	45.1	46.0	44.9	45.9	46.2	46.6

* Extracted from the article Climate in the Supplement to the Encyclopedia Britannica.

The observations from which the above table is compiled, were made in the most satisfactory manner by the directions, and under the superintendence, of Mr Ferguson of Raith, in his garden, at Abbotshall, about 50 feet above the level of the sea, and nearly a mile from the shore of Kirkaldy, in latitude 56° 10′. The thermometer, at the depth of one foot, reached its maximum and minimum temperatures about three weeks after the summer and winter solstices: its extreme variation being 25°. The thermometer, at the depth of two feet, reached its maximum and minimum temperatures about four or five weeks after the solstices: its extreme variation being 20°. The thermometer at the depth of four feet did not reach its maximum and minimum temperatures, till nearly two months after the solstices: its range being only 15°. And the thermometer, at the depth of eight feet, did not reach its maximum and minimum temperatures, till nearly three months after the solstices of summer and winter: and its range was only 9½°. These facts show the slowness with which the increased temperature, during summer, penetrates the earth; and the corresponding slowness with which it is again returned to, and emanates from the surface of the ground during the cold season of the year.

Of the variations in the temperature of water at different depths, &c.—The oscillations in the temperature of the ocean, and also of deep lakes above and below the mean for the latitude, is restricted in a great measure to the surface. Below the depth of fifteen or twenty fathoms, the annual variations of temperature are not perceptible. In fresh-water, when

the temperature at the surface is above 39°, the temperature sinks as the depth becomes greater, until it nearly reaches that point, when it remains stationary; and gradually as it approaches that point, the decrements of temperature, for equal increments of depth, become less. On the contrary, when the temperature of the surface is below 39°, the temperature increases with the depth, till it reaches that point, and at all farther depths remains stationary. This is owing to the mobility of water, in connection with the statical law of its particles becoming heavier, with increase of coldness, till they reach their maximum density at 39°. Hence all the cold impressions communicated to the surface, so long as the temperature remains above 39°, are transmitted downwards by the sinking of the cold particles, while the warm impressions remain chiefly on the surface, till dissipated by evaporation, or radiation. The following observations, as well as others, (which, for the sake of brevity, we omit inserting,) confirm the truth of these remarks:—On the 11th September, the superficial water of Loch Katrine being 57° 3′, the thermometer let down ten fathoms indicated 50° 6′; at the depth of twenty fathoms, it indicated 43° 1′; and near the bottom, at 80 fathoms, it indicated 41°. Saussure found the temperature of the Lake of Geneva, at the depth of 1000 feet, to be 42°, and could discover no monthly variations under 160 feet. These observations afford an explanation of the reason why the surface of deep lakes, even in moderately high latitudes, never freezes. Owing to the maximum density of water being at 39°, gradually as the particles on the surface get cooled below that

point, they sink to the bottom. Consequently, before the surface can be frozen, or even before its temperature can be reduced below 39°, the temperature of the whole water to the bottom must be lowered to that point. But the duration of cold weather, unless in very high latitudes, is usually too short to produce this effect, where the depth of water is considerable.

Between the tropics, and also in the temperate zone, where the temperature of the surface of the ocean is above that at which its density is greatest, its temperature diminishes with the depth; whereas, in the Polar seas, where the heat at the surface is below that at which its density is greatest, the temperature augments with the depth. The temperature of the surface of the ocean has been found gradually to decrease from the equator to the 70th parallel of latitude, where it remains stationary. It is, therefore, about this parallel where the mean temperature of the ocean is nearly constant at all depths.

The great coldness experienced at the bottom of deep caverns, and uncovered pits, and draw-wells, has been explained upon the same principle as the coldness near the bottom of deep lakes. During the depth of winter, the cold air at the top of the cavern, from its superior specific gravity, sinks down to the bottom. But in summer, the warm air at the mouth of the cavern, owing to its inferior specific gravity, has no tendency to sink down and displace the cold air below.

Of the maximum, minimum, and mean diurnal temperatures.—Within the tropics, the maximum diurnal temperature occurs about an hour after mid-

day; and gradually as we advance from the tropics to higher latitudes, at least during summer, it becomes later in the afternoon. The circumstance of the maximum diurnal temperature occurring sooner or later after mid-day, seems chiefly to depend upon the degree of rapidity, with which the falling of the sun's rays upon the earth's surface increase in obliquity after mid-day. Hence in temperate and high latitudes, the nearer the summer solstice, the longer is it after mid-day before the maximum diurnal temperature occurs. At Glasgow, situated in north latitude 55° 52′, the maximum diurnal temperature, as indicated by a thermometer shaded from the direct and reflected rays of the sun, occurs at the summer solstice, about three hours after mid-day; whereas, at the winter solstice, it takes place about an hour and a half after mid-day. In higher latitudes it will occur sooner after noon in winter; and later after noon in summer, than at Glasgow. Upon this point it may be remarked, that the differences among meteorologists as to the length of time after mid-day, when the maximum temperature occurs, are not wholly to be ascribed to the difference in the latitude, and the season of the year when the observations are made. They also result from peculiarities around the place of observation, giving more or less hinderance to the progress of the calorific tide. The tides of the ocean are longer of attaining their greatest height at any place, according to the number of sinuosities and obstructions which they have to encounter in their course. And in like manner, the calorific tide of day is longer of attaining its maximum height, according

as the place of observation is better fitted for retarding its approach. Of two thermometers which I have been in the habit of observing, one was nearly an hour later of reaching its maximum diurnal temperature than the other. And analogously to the diminution in the annual range of temperature, exhibited by thermometers, according as they were sunk deeper in the ground, the diurnal range of temperature exhibited by the thermometer which was best protected from the solar heat, and which was latest of arriving at its maximum height, was least.

In similar parallels of latitude, it is said that the maximum diurnal temperature occurs sooner at sea than on land. But both by sea and land, and in all latitudes, and seasons of the year, the minimum diurnal temperature takes place about an hour before sunrise.

Various plans have been adopted for ascertaining the mean diurnal temperature. One of these is to take the mean between the maximum temperature of day, and the minimum of night. Another plan, but hardly so good as the preceding, is to take the mean between the temperatures of 10 o'clock, A.M. and 10 o'clock, P.M.; others take the mean between 9 o'clock, A.M. and 9 o'clock, P.M. But the most perfect plan that has been proposed, is to observe the temperature every hour during day and night for a length of time together, and to take the mean of the whole. According to Humboldt, between the parallels of 46 and 48, the thermometer, at the moment of sunsetting, indicates in every season, very nearly the mean atmospheric temperature of the day. This rule of Humboldt's, however, will be found exceedingly defective

if applied generally. For instance, about mid-summer, particularly in high latitudes, when the days are very long, the instant of sunsetting will indicate a diurnal temperature much below the mean; whereas, about mid-winter, in high latitudes, when the days are very short, the instant of sunsetting will indicate a diurnal temperature much above the mean.

Of the mean annual temperature in different latitudes.—The following table, made out by Professor Mayer of Gottingen, of the mean annual temperature for each degree of latitude from the Equator to the Poles, is the one generally adopted:—

Lat.	Centesimal.	Diff.	Fahrenheit.	Diff.
0	29.00	.00	84.2	.00
1	28.99	.01	84.2	.02
2	28.96	.03	84.1	.05
3	28.92	.04	84.0	.07
4	28.86	.06	83.9	.11
5	28.78	.08	83.8	.13
6	28.68	.10	83.6	.18
7	28.57	.11	83.4	.20
8	28.44	.13	83.2	.23
9	28.29	.15	82.9	.27
10	28.13	.16	82.6	.30
11	27.95	.18	82.3	.32
12	27.75	.20	82.0	.36
13	27.53	.22	81.6	.40
14	27.30	.23	81.1	.42
15	27.06	.24	80.7	.44
16	26.80	.26	80.2	.47
17	26.52	.28	79.7	.50
18	26.23	.29	79.2	.52
19	25.93	.30	78.7	.54
20	25.61	.32	78.1	.57
21	25.28	.33	77.5	.60

Lat.	Centesimal.	Diff.	Fahrenheit.	Diff.
22	24.93	.35	76.9	.63
23	24.57	.36	76.2	.65
24	24.20	.37	75.6	.67
25	23.82	.38	74.9	.68
26	23.43	.39	74.2	.70
27	23.02	.41	73.5	.72
28	22.61	.42	72.7	.74
29	22.18	.43	71.9	.76
30	21.75	.43	71.1	.77
31	21.31	.44	70.3	.79
32	20.86	.45	69.5	.81
33	20.40	.46	68.7	.83
34	19.93	.47	67.9	.84
35	19.46	.47	67.0	.85
36	18.98	.48	66.2	.86
37	18.50	.48	65.3	.87
38	18.01	.49	64.4	.88
39	17.50	.49	63.5	.88
40	17.01	.49	62.6	.89
41	16.52	.49	61.7	.90
42	16.02	.50	60.8	.90
43	15.52	.50	59.9	.91
44	15.01	.51	59.0	.91
45	14.50	.51	58.1	.92
46	13.99	.51	57.2	.92
47	13.49	.50	56.3	.91
48	12.98	.51	55.4	.91
49	12.48	.50	54.5	.90
50	11.98	.50	53.6	.90
51	11.49	.49	52.7	.89
52	10.99	.50	51.8	.90
53	10.50	.49	50.9	.88
54	10.02	.48	50.0	.87
55	9.54	.48	49.2	.86
56	9.07	.47	48.3	.85
57	8.60	.47	47.5	.84
58	8.14	.46	46.6	.83
59	7.69	.45	45.8	.81
60	7.25	.44	45.0	.79

Lat.	Centesimal.	Diff.	Fahrenheit.	Diff.
61	6.82	.43	44.3	.78
62	6.39	.43	43.5	.77
63	5.98	.41	42.8	.76
64	5.57	.41	42.0	.74
65	5.18	.39	41.3	.71
66	4.80	.38	40.6	.68
67	4.43	.37	40.0	.67
68	4.07	.36	39.3	.65
69	3.72	.35	38.7	.63
70	3.39	.33	38.1	.60
71	3.07	.32	37.5	.57
72	2.77	.30	37.0	.54
73	2.48	.29	36.5	.52
74	2.20	.28	36.0	.50
75	1.94	.26	35.5	.47
76	1.70	.24	35.1	.43
77	1.47	.23	34.6	.41
78	1.25	.22	34.2	.40
79	1.05	.20	33.9	.36
80	.86	.19	33.6	.34
81	.71	.17	33.3	.31
82	.56	.15	33.0	.27
83	.43	.13	32.8	.23
84	.32	.11	32.6	.20
85	.22	.10	32.4	.18
86	.14	.08	32.3	.15
87	.08	.06	32.2	.11
88	.04	.04	32.1	.07
89	.01	.03	32.0	.05
90	.00	.00	32.0	.01

Upon the above table it may be remarked, that in high latitudes, where ice and snow are perpetually to be found, the mean annual temperature given is much higher than it ought to be. The Professor's statement of the mean annual temperature at the pole being 32° of Fah. is founded upon the fact, that the ice is neither increasing nor decreasing. He forgets,

however, that the freezing point of salt water is considerably lower than that of fresh. Water saturated with salt does not freeze till the temperature sinks to about 5° of Fah.; and even with the moderate amount of salt that sea water usually contains, instead of freezing at 32°, it does not begin to freeze till the temperature sinks to 28° or 29°. Instead of 32°, therefore, 28° or 29° ought to have been the mean temperature, according to the principle upon which the Professor's estimate of the temperature in high latitudes is founded. But judging from the facts communicated by Captains Scoresby and Parry, regarding the atmospheric temperature in high latitudes, even 28° or 29° is greatly above the mean annual atmospheric temperature at the pole. During the time Captain Parry remained at Melville Island, the thermometer in the ship was often observed as low as —50°; and at a distance from the ship, even as low as 55 degrees below zero;* and judging from the fact that the distance between Melville Island and the pole is upwards of 1000 miles, and that for a similar distance all around the pole there is perpetual ice and snow, it is presumable, that the temperature at the pole is frequently, during winter, considerably under —55°. Now, though the circumstance of the ice in the vicinity of the pole, being neither upon the increase nor the decrease, proves, that the amount of heat which the ice and water there receives during summer is the same as that given off during winter, it does not prove that

* The lowest temperature hitherto produced artificially is 91° under zero of Fahrenheit.—*Dr Prout's Bridgewater Treatise.*

the mean annual temperature of the atmosphere, a few feet above the ice, (which is always understood, when temperature without any specification is mentioned,) is the same as that at which sea water freezes, viz. 28° or 29°. So long as the surface of the sea and of the land is covered with unmelted ice or snow, the heat communicated by the sun during summer, is absorbed by the melting ice or snow; and the temperature of the incumbent atmosphere seldom rises, in such circumstances, higher than about five or six degrees above that at which snow and ice melt. While, therefore, the atmospheric temperature at the pole may be five or six degrees above the freezing point of sea water, for four or five months during summer, it is probably from 40° to 80° below the freezing point of sea water, for a corresponding length of time during winter. Hence I conclude, that the mean annual atmospheric temperature at the pole is not above zero of Fahrenheit.

It may be farther remarked, that though the preceding table may give a tolerably correct statement of the mean annual temperature for each latitude at sea, and for small islands and places bordering on the sea; it will be found much too high for all inland countries in high or temperate latitudes, and too low for inland countries within the torrid zone.

Of the causes which modify the mean annual temperature on land in different latitudes.—Of the line of perpetual congelation, and glaciers.—On land, the mean annual temperature for any given latitude is modified by various circumstances. Thus it is lowered by every increase in the altitude of the place of

observation above the level of the sea. It is also lowered by ice or snow frozen or deposited during winter, being in the neighbourhood, whether on mountains or elsewhere. It is likewise lowered by every increase in the amount of water evaporated from the soil, at or near the place of observation. It is also lowered by every increase in the prevalence of northerly winds in the northern hemisphere, and of southerly winds in the southern hemisphere; and raised by every increase in the prevalence of winds blowing from the contrary directions, in the respective hemispheres.

The first of these circumstances which we shall notice, is difference in the elevation of different places above the level of the sea. We formerly mentioned, that the temperature of the atmosphere decreased at the rate of one degree of Fahrenheit, for every 300 feet of perpendicular ascent. Of course, in determining the mean annual temperature of any place by means of the table, a deduction at the above rate of one degree requires to be made, for every 300 feet it stands above the level of the sea.

According to the law by which the temperature decreases with the perpendicular altitude above the level of the sea, it is obvious, that at a certain elevation, which decreases from the equator towards either pole, the mean temperature must be as low as the freezing point. Above this altitude, which is called *the line of perpetual congelation*, snow remains unmelted all the year round. The following table, computed by Kirwan, exhibits the altitude of the line of perpetual congelation above the level of the sea, for

every five degrees of latitude from the equator to the pole.

Lat.	Mean height of term of congelation.
0	15,577 feet.
5	15,457
10	15,067
15	14,498
20	13,719
25	13,030
30	11,592
35	10,664
40	9,016
45	7,658
50	6,260
55	4,912
60	3,684
65	2,516
70	1,557
75	748
80	120

The above table in very high latitudes is evidently erroneous. The line of perpetual congelation at the level of the sea, even for salt water, commences where navigation towards either pole is interrupted by ice. This occurs in the northern hemisphere at a much lower parallel of latitude than the 80th; and, according to the accounts of Captain Cook, the ice around the south pole extends to a much lower latitude than that which surrounds the north.

Within the torrid zone, owing to the annual variation of temperature being very small, the snow forming the line of perpetual congelation, on any elevated range of mountains, such as the Andes in South

America, is distinctly marked, and continues throughout the year without almost any alteration in its height. As we recede from the tropics towards either pole, owing to the increasing difference between the extreme temperatures of summer and winter, the height at which the snow line commences is subject to considerable variation. It rises with the increasing heat of summer, and again sinks upon the approach, and during the continuance of winter. For obvious reasons, it is also higher on the southern side of mountains, in the northern hemisphere, than on their northern side; and *vice versa*, higher on the northern side of mountains, in the southern hemisphere, than on their southern side.

What are called Glaciers originate chiefly in the broad zone or belt, which exists only in temperate and high latitudes, between the summer and winter lines of perpetual congelation. They are generally to be found occupying elevated valleys, surrounded by more elevated mountains. They consist of winter snow partially melted during summer, and again frozen into ice during winter. In consequence of the snow that falls during winter upon the glaciers, being assisted by additional supplies, in the form of avalanches, from the neighbouring mountains, they extend their icy frontiers to a much lower altitude than even the winter line of perpetual congelation. From Mont Blanc to the borders of the Tyrol, it is said there are no fewer than 400 glaciers, the greater part of which are six or seven leagues long, by one half, or three quarters of a league wide, and from 100 to 600 feet thick. A very few of these are so small as a league in length. M. Ebel

has calculated, that their aggregate extent would form a single glacier of 150 square leagues. During summer, these immense fields of eternal ice, aided by the snow on the mountains, become, for reasons hereafter to be explained, centres from whence cold currents of air diverge in every direction. Consequently, they lower the mean annual temperature, not only in their immediate vicinity, but to a great distance around. And this effect is produced, like that which is occasioned by the ice around the poles, and by mountain snow in general, chiefly in consequence of the heat of the sun's rays being absorbed by the melting snow and ice during day and summer. Hence ice and snow reduce the surrounding mean annual temperature of the atmosphere, principally by lowering the summer temperature, or rather perhaps by preventing the rise which would otherwise then take place ; while, in consequence of the water resulting from the melting ice and snow being carried off by rivers, without being again frozen, they have no influence in raising the temperature during winter.

The mean annual temperature, in any given latitude, is also lowered by every augmentation in the amount of water evaporated from the soil, at or near the place of observation. In all places, upon the same parallel of latitude, the amount of heat annually derived from the sun's rays may be considered equal. Consequently, every thing which increases the rapidity with which that heat is again carried off, lowers the mean annual temperature. Now evaporation is one of the principal means by which the solar heat communicated to the earth is again carried off. Water,

in its transition to vapour, absorbs no less than about 940 degrees of temperature; and hence, whatever increases the amount of water evaporated, lowers the mean annual temperature of the district and neighbourhood where it occurs. The mean annual temperature of moor-land, and undrained districts of a country, is generally found to be somewhat lower than those that are cultivated and properly drained: and this is almost exclusively to be ascribed to the greater amount of moisture evaporated from the former, than from the latter. Such districts, in consequence of want of draining, almost always present a moistened surface, so that evaporation goes on without almost any interruption; whereas, the surface of cultivated and well-drained lands is frequently for lengthened periods dry, and evaporation is consequently suspended. Hence the reason that the quantity of moisture annually evaporated from undrained lands is greater, than from those that are drained and properly cultivated.

In like manner, the mean annual temperature of mountains, and of hilly and elevated lands in general, is reduced by increased evaporation below what they would be otherwise, even after due allowance is made for their elevation above the level of the sea. The increased evaporation, in such situations, is owing partly to the more abundant supply of rain causing them to present a more constantly moistened surface; and partly to such localities being more exposed to the evaporative influence of the wind; and partly also to the large proportion of boggy undrained lands, which are always to be found in mountainous or hilly districts.

The mean annual temperature for the latitude is also very much affected, by the prevalent direction and force of the winds in different localities. Thus northerly winds in the northern hemisphere, and southerly winds in the southern, by transporting the cold air of a cold to a warmer climate, reduce the temperature. And, on the contrary, southerly winds in the northern hemisphere, and northerly winds in the southern, by transporting the warm air of a warm to a colder climate, raise the temperature. And the stronger such winds are, by allowing less time to the air to become warm or cold during its progress, the greater their efficacy in reducing the temperature in the one case, and augmenting it in the other. Upon this point, however, it may be remarked, that northerly or southerly winds have little influence in either depressing or raising the temperature during summer, especially during its latter half, compared to what they have during winter. The reason is, that the greater length of the day during summer, as the latitude becomes higher, compensates in a great measure for the greater obliquity with which the sun's rays fall upon the earth. And consequently, differences of latitude, unless very great, then produce very little difference in the mean diurnal temperature. Thus the mean diurnal temperature at mid-summer, will be nearly as great at the latitude of 60°, as at that of 40°; but at mid-winter it will be very different. Hence the mean annual temperature of any place is much more affected by the greater or less prevalence of northerly or southerly winds during the cold, than during the warm, season of the year.

Again, owing to the smallness in the annual range

of the temperature of the ocean, compared to that of the land, a wind from the ocean, and blowing along the same parallel of latitude, is much warmer during winter, and much colder during summer, than a wind from the land. Consequently, on continental coasts, the mean annual temperature is augmented by the prevalence of winds from the ocean during the coldest period of the year, and from the land during the warmest. On the contrary, the mean annual temperature of such localities is reduced by the prevailing direction of the winds, being from the land during winter, and from the ocean during summer.

The influence of the prevailing direction of the wind is exemplified along the northern shores of Africa. Owing to the prevailing wind in that region of the globe being from the Mediterranean, lying to the north, the climate is cool, moist, and salubrious, for the latitude, with the exception of about a fortnight in the course of a year, when the wind blows from the sandy desert lying to the south, and which is attended with a degree of heat and dryness, that makes it almost resemble the scorching blast issuing from a furnace.

Of the decrement in the mean annual temperature, upon receding from the ocean, to the north of the 30th parallel of latitude, and of isothermal lines.— Playfair says: "As we go eastward from the shores of the Atlantic, the mean temperature of any parallel becomes lower, at a rate that may perhaps, for the north part of the temperate zone, be estimated at a degree for 150 miles.

"At St Petersburgh, lat. 59° 56′, about 750 miles

from what may be accounted the shores of the Atlantic, the temperature is 5° 5′ below the standard. The medium temperature of January is no more than 10°. By computation it ought to be greater than 32°. The winter lasts from October to April, and the cold is sometimes as great as the freezing point of mercury, or —39°. From a mean of several years the mean of the winter cold is —25°.

"It was at Krasnojark, lat. 56° 30′, long. 93° east, that mercury was first known to freeze by natural cold.

"If we were to begin where any parallel intersects the shore of the Atlantic, and draw on a map a line along which the mean temperature should be constantly the same as at the first-mentioned point, it would incline greatly to the south. The point, for instance, in the meridian of St Petersburgh, which has the same temperature with the standard belonging to the parallel of that city, is about 5° south of it, or in the latitude of 54° 30′ nearly.

"In Irkutz, latitude 52° 15′, longitude 105° east, the mean temperature from October to April has been known to be as low as 6° 8′ below zero, a temperature which for severity and duration exceeds any thing that has yet been observed elsewhere.

"This increase of the severity of the winter, and the consequent diminution of the mean temperature, on going eastward, holds in all the latitudes north of the parallel of 30°; but the diminution is slower as we approach that parallel; and to the south of 30°, the mean heat increases on retiring from the ocean.

"This diminution takes place all the way to the shores of the Pacific, or very near them. The climate

of Pekin is vastly more severe than that of the same parallel (39° 54′) in Europe."

The diminution of the mean annual temperature upon receding from the ocean in all latitudes higher than the 30th parallel, has been exhibited in a perspicuous manner by Humboldt, by means of what are called isothermal lines drawn upon a map. He divides the northern hemisphere into the following six isothermal bands, or zones of equal temperature, viz. :—

1	The zone of mean annual temperature ranging	from 32 to 41
2	————————————	from 41 to 50
3	————————————	from 50 to 59
4	————————————	from 59 to 68
5	————————————	from 68 to 77
6	————————————	from 77 upwards.

Appended to this volume is a map, on which are delineated the isothermal lines bounding the various zones above described, and also a table of the temperatures of the more important places contained in the several isothermal zones.

Describing the distribution of temperature over the northern hemisphere, Humboldt says :—

"The whole of Europe compared with the eastern parts of America and Asia, has an insular climate; and upon the same isothermal line the summers become warmer, and the winters colder, as we advance from the meridian of Mont Blanc towards the east or the west. Europe may be considered as the western prolongation of the old continent; and the western parts of all continents are not only warmer, at equal latitudes, than the eastern parts; but even in the

zones of equal annual temperature, the winters are more rigorous, and the summers hotter, on the eastern coasts, than on the western coasts of the two continents. The northern part of China, like the Atlantic region of the United States, exhibits seasons strongly contrasted; while the coasts of New California, and the embouchure of the Columbia, have winters and summers almost equally temperate. The meteorological constitution of countries towards the north-west, resembles that of Europe as far as 50° or 52° of latitude. Comparing, in the two systems of climates, the concave and the convex summits of the same isothermal lines; we find at New York, the summer of Rome, and the winter of Copenhagen ; at Quebec, the summer of Paris, and the winter of St Petersburgh. At Pekin, also, where the mean temperature of the year is that of the coasts of Brittany, the scorching heats of summer are greater than at Cairo, and the winters are as rigorous as at Upsal. So also, the same summer temperature prevails at Moscow in the centre of Russia, as towards the mouths of the Loire, notwithstanding a difference of 11° of latitude ; a fact that strikingly illustrates the effects of the earth's radiation, on a vast continent deprived of mountains. This analogy between the eastern coasts of Asia and America sufficiently proves," continues Humboldt, " that the inequalities of the seasons depend on the prolongation and enlargement of continents towards the pole ; on the size of seas in relation to their coasts ; and on the frequency of north-west winds ; and not on the proximity of some plateau, or elevation, of the adja-

cent lands.* The great table lands of Asia do not stretch beyond 52° of latitude; and in the interior of the new continent, all the immense basin, bounded by the Alleghany range, and the Rocky mountains, is not more than from 656 to 920 feet above the level of the ocean."

Such are the facts as stated by Playfair and Humboldt, the causes of which we will now endeavour to point out.

One reason for the reduction of the mean annual temperature upon going eastward from the shores of the Atlantic, is the greater prevalence of northerly winds. In Great Britain, and in general along the western shores of Europe, by far the most prevalent wind is from the south-west. Indeed, northerly winds, that is, winds blowing from the north of due east or west, are in this island, and along the western shores of Europe, rare, and their force is almost always inconsiderable, when compared with winds blowing from the south of due east, or due west. Hence the mean annual temperature of Europe, and particu-

* The opinion above expressed by Humboldt is not altogether correct. Proximity to mountains and elevated lands, has been universally observed to have some influence in lowering the mean annual temperature of the surface of the earth. In previous passages, to which we refer, we have attributed this result, partly to the absorption of the solar heat during day and summer, by the melting of ice and snow deposited on mountains during winter; and partly to evaporation of moisture, and the cooling influence therefrom resulting, being greater in mountainous and hilly districts, than in low-lying champaign countries, where, comparatively, little rain falls, and where the surface of the ground is dry during a larger proportion of the year.

larly of its western portions, is much augmented, in consequence of the prevailing south and south-west winds transporting a warm atmosphere to a comparatively cold climate. On the contrary, over a large proportion of Asia, and the eastern parts of Europe; and in general as we go eastward from the shores of the Atlantic, northerly winds become more prevalent. Accordingly, the mean annual temperature, in such regions of the earth, is reduced in consequence of the prevailing winds transporting a cold atmosphere to what would otherwise be a comparatively warm climate.

Another cause of the reduction of the mean annual temperature as we go eastward from the shores of the Atlantic, is the increasing hygrometric dryness of the atmosphere on receding from the ocean. Over Great Britain, and along the western shores of Europe, the atmospheric temperature is somewhat supported, especially during winter, by the heat evolved during the condensation of invisible vapour into the visible states of dew, mist, and cloud. In addition likewise to the heat obtained while clouds and mist are forming, clouds and mist are essentially useful during night and winter, (which are the seasons when they are most prevalent,) in preventing the heat absorbed by the earth during day and summer, from escaping by radiation from its surface. On the contrary, in far inland countries, owing to the hygrometric dryness of the atmosphere, almost no dew is deposited, and little mist, and few clouds are formed; and of course, the atmosphere therefrom derives little heat; and the usual cloudless state of the sky affords a greater facility to

the caloric absorbed during day and summer, to escape by radiation during night and winter.

Another cause of the reduction in the mean annual temperature, on going eastward from the shores of the Atlantic, is, that the temperature of the lower atmospheric strata, where thermometric observations are always made, is more affected by a sinking, than by a rise of temperature. Thus Playfair says: "The greatest heat is much less above the mean temperature than the greatest cold below it. The mean temperature for the whole surface of the earth may be taken at 58°; the greatest summer heat is only 42° above this; the greatest winter cold is 98° under it." The explanation of this fact is the following:—During day and summer, though the atmospheric strata nearest the ground become warmer, they simultaneously become specifically lighter than those above. Hence the augmentation of temperature near the ground, during day and summer, is reduced below what it would otherwise be, by the interchange of position between the higher and lower atmospheric strata, which is then constantly, though slowly and imperceptibly, going on. On the contrary, during night and winter, when the atmospheric strata nearest the ground become colder than those above, as was determined by the observations of Dr Wells, they also become specifically heavier, and accordingly, no intermixture of the higher and lower atmospheric strata then takes place. Of course, the counteraction to the augmentation of temperature in the one case, and the want of counteraction to its depression in the other, satisfactorily account for the depression of tem-

perature which the lower atmospheric strata undergo during night and winter, being greater than the augmentation during day and summer.

Now, since the depression of temperature below the mean for the latitude, during night and winter, is always greater than the augmentation above the mean during day and summer, it follows, that the greater the annual range of temperature is, the greater will be the reduction of the mean annual temperature for the latitude. It was formerly stated that the mean annual range of temperature is much less over the ocean than over the land; and, owing to the interchange in the atmospheric temperature that takes place between contiguous localities, the diurnal and annual range in general becomes less over the land, the nearer we approach the shores of the ocean. In small islands, therefore, where the annual range of temperature is either the same, or very little more, than that of the ocean which surrounds them, the mean annual temperature is much higher than in places far inland on the same parallel of latitude, provided it be beyond the 30th parallel.

Besides, the mean annual temperature of inland countries is frequently reduced, in consequence of the summer heat being absorbed by the melting of snow deposited during winter. Thus, in the kingdom of Thibet, which constitutes the highest table-land in Asia, the snow deposited on the mountains contributes to render its climate cold and inhospitable, which, notwithstanding its general elevation above the level of the sea, should be comparatively mild. "At 28° 18′ of north latitude, in the kingdom of Thibet,

not far from the torrid zone, the wind," says Captain Turner, "was violently high in the month of September, and so sharp, that we dared not expose our faces to its fury: the want of caution on the preceding day had left on our faces sad memorials of its keen rudeness, and we now rode muffled up in such a manner that we could but just breathe. Such also is the intensity of frost in this quarter, that animals exposed in the open fields are not unfrequently found dead, with their heads absolutely split by its force. On the summits of the hills springs are often seen arrested in their fall by frost, and converted into solid monuments of ice, firmly fixed till the heat of summer dissolves them. Some of them are of prodigious bulk and altitude, resembling immense columns, contributing, with the universal nakedness of both hills and valleys, to impress on the mind of the traveller an indelible conviction of the bleakness of the region, and the severity of the climate."

Of the increment in the mean annual temperature, upon receding from the ocean, within the 30*th parallel of latitude.*—The reason why the mean annual temperature increases on retiring from the ocean nearer the equator than the 30th parallel of latitude, is owing to the amount of moisture evaporated from the land, (and which diminishes on receding inland,) being much less than the amount evaporated from the ocean in corresponding latitudes, while the other causes previously enumerated, which produce cold in inland countries, to the north of the 30th parallel, have in a great measure ceased to operate. Nearer the equator than the 30th parallel of latitude, the falling of rain is

usually restricted to three or four months in the year. Accordingly, during the greater part of the year, evaporation is suspended, in consequence of the surface of the land being thoroughly dried up; whereas, from the surface of the ocean, evaporation goes on throughout the year. Judging from the great heat communicated by winds blowing from the immense sandy desert of Sahara, in Africa, it is probable that the mean annual atmospheric temperature, in its more central portions, is upwards of 100°; whereas, the mean annual atmospheric temperature over the ocean, at the equator, is only 85°.* This great difference in the mean temperature, I ascribe to the heat communicated by the solar rays, being almost undiminished by evaporation, in the former case, while it is thereby greatly reduced in the latter.

Of the mean temperature of America, relative to that of Europe.—In North America, the mean annual temperature is lower, and the severity of winter greater, than in corresponding latitudes in Europe. Playfair says: "At Prince of Wales' fort, Hudson's Bay, lat. 59°, long. 92° west, the mean temperature is 20° under the standard; at Nain, in Labrador, 16°; at Cambridge, in New England (lat. 42° 25′) 10 degrees. Mercury has been supposed to be frozen by the natural cold as far south as Quebec, lat. 47°."

"The low mean annual temperature in North America, compared with that of Europe in corresponding latitudes, may be ascribed partly to the surface of the land being more generally covered with forests; but

* According to Humboldt, the mean annual temperature at the equator is only $81\frac{1}{2}$°; but this is generally considered too low.

it is principally owing to the want of draining, by which a large proportion of the rain that falls is again evaporated, and of course a smaller proportion is returned to the sea by rivers. "Forests," says Playfair, "tend to increase the cold by preventing the sun's rays from striking the ground. Evaporation produces cold; and marshes and lakes are therefore favourable to the severity of the weather."

Upon this quotation it may be remarked, that though forests prevent the sun's rays from striking the ground, they can hardly be said, on this account, to increase the cold; because they do not diminish the annual amount of solar heat communicated. Their influence in reducing the mean annual temperature, seems to be owing, partly to the circumstance of their being in foliage in summer, while they are without leaves in winter. Consequently, they are more efficacious in preventing the subjacent ground from acquiring heat from the sun's rays during summer, than in obstructing its escape by radiation during winter. And owing to the great extent of surface which trees present to the atmosphere, what heat they themselves acquire during day and summer, is very speedily dissipated during night and winter. The influence of forests, however, in reducing the mean annual temperature, is principally to be ascribed to their agency in increasing evaporation, by presenting a larger evaporating surface to the action of the atmosphere, than cleared land.

Connected with the influence of evaporation upon the mean temperature, it may be remarked, that a more extended system of what is called tile-draining,

and all other means by which a larger proportion of rain-water is returned to the sea by rivers, instead of being evaporated from the soil, will tend to raise the mean annual temperature of those countries, and those districts of countries where it is generally introduced. Hence it is probable, that lands which are at present cold, bleak, barren, and seemingly unfit for cultivation, will, by proper draining, be ultimately rendered comparatively warm, dry, and productive.

Of the coldness of Europe in ancient times.—Of modifications in the temperature of the ocean in different places, &c.—The reasons assigned for the greater coldness of the climates of Europe in ancient times, compared to what they are at present, are the same as those which produce the superior coldness in North America, compared with the same parallels of latitude in Europe. Playfair, quoting Cæsar, says, " that the vine could not be cultivated in Gaul on account of the severity of the winter. The rein-deer was then an inhabitant of the Pyrenees. The Tiber was sometimes frozen over, and the ground about Rome covered with snow for several weeks together." In explanation of these phenomena, Playfair makes the following observations:—" Cultivation may improve a climate, 1*st*, By the draining of marshes, and lessening the evaporation, which is so great a cause of cold; 2*d*, By turning up the soil, and exposing it to the rays of the sun; 3*d*, By thinning or cutting down forests, which by their shade, prevented the penetration of the sun's rays. The improvement which is continually taking place in the climate of North America, proves that the power of man ex-

tends to the phenomena, which, from the magnitude and variety of their causes, appear most beyond its reach. At Guiana, in South America, the rainy season has been shortened by the clearing of the country, and the warmth has been greatly increased. It thunders continually in the woods, rarely in the cultivated parts."

The mean temperature in particular places in the ocean, is somewhat modified by the waters discharged into it by rivers, the temperature of which varies with that of the land from whence it is derived. It is also modified in particular tracks by currents originating within its own boundaries. The chief of these is the Gulf stream. This immense current is supposed to be produced by the influence of the friction of the trade wind on the surface of the Atlantic, in depressing the level of the ocean in the equatorial regions near the coast of Africa, and elevating it in the Gulf of Mexico. This circumstance being farther assisted by the influence of the tides, and by the peculiarly well-fitted curved configuration of the land for giving birth to a current through the Gulf of Florida. After passing through this outlet, it directs its course in nearly a straight line towards the north-east by north; and in this direction it has been traced to very high latitudes in the Atlantic. Wherever it has been traced, its temperature is from two to five degrees warmer, than that of other parts of the Atlantic, equally distant from the equator.

The cause of the cold being greater in the higher latitudes of the southern hemisphere than in the northern, Playfair says, is "by no means sufficiently

understood." It is probably chiefly owing to the influence of the Gulf stream; and it may possibly be assisted by the greater proximity of the sun to the earth during what is summer in the southern hemisphere, not sufficiently compensating both for the consequently slightly increased obliquity with which his rays then fall upon high southern latitudes; and for the shorter time that he remains on the south side of the equator.

Of the diminution in the annual range of temperature, upon approaching the ocean, &c.—The diminution in the annual range of temperature in any given latitude, according as the place of observation is nearer the ocean, is to be ascribed to the proportionally greater facility with which the temperature of the ocean is, in such circumstances, communicated by aerial currents to the land. In the small island of Grenada, in the West Indies, the temperature in the shade is maintained so uniform throughout the year, by means of sea and land breezes, that it never exceeds 85°, and never sinks below 80°, being an annual range only of 5°. At Glasgow, the greatest heat of summer in ordinary years does not exceed 75° of Fah., and it is seldom that it sinks below the temperature of 20°, being an average annual range of 55°. At Rothsay, in the Island of Bute, which lies nearer the Atlantic, the annual range of temperature is under 40°, being at least 15° less than what it is at Glasgow. The temperature will more frequently rise above 75° at Glasgow, than above 70° at Rothsay; and oftener sink below 20° at Glasgow, than below 30° at Rothsay. 78° is about the highest temperature the thermometer

has been observed to reach at Glasgow, and this degree of elevation it attained last summer, (1834). Fourteen degrees below zero, was the lowest that I ever heard of it having fallen to; and this occurred one morning before sunrise, in the remarkably severe winter of 1813-14. At St Petersburgh, the temperature usually rises about the warmest period of summer to 75° or 80°; and during the coldest period of winter sinks to about 40° below zero, making an annual range, in ordinary years, of no less than from 115° to 120° of Fahrenheit.

Within, and in the vicinity of, the arctic circle, the annual range of temperature, contrary to what might be expected, is less than what it is in inland countries lying in temperate latitudes. This is owing to the diminution of the winter's cold, produced by the evolution of heat, during the freezing of water; and to the diminution of the summer's heat, occasioned by the absorption of caloric, during the melting of ice and snow, which are constantly to be found in those regions.

Of Professor Lyell's hypothesis regarding the variation in the mean temperature, as affected by the proportions of land and water.—The fact of the mean annual temperature decreasing beyond the 30th parallels of latitude, and increasing within them, according as we recede from the ocean, has been had recourse to in order to account for phenomena that are involved in much mystery. Thus Professor Lyell, from a variety of geological facts, concludes, that in times anterior to historical records, the temperature throughout the northern hemisphere, in the latitudes

now occupied by Europe, Asia, and America, has undergone a great diminution. This he endeavours to account for, by supposing that alterations in the proportions of land and water in the equatorial and polar regions must have taken place. He conceives that land in high latitudes, particularly if elevated, such as exists in the northern parts of North America, contributes to lower the mean temperature of neighbouring countries; and that land in equatorial regions, such as Africa, raises the mean temperature of all surrounding countries. Hence he concludes, that whenever a greater extent of land is collected in the polar regions, the cold will augment; and that the same result will be produced when there shall be more sea between and near the tropics; and *vice versa.*

The truth of the preceding hypothesis is by no means well established. In accordance with our previous observations, it must be admitted that an increase of land in the equatorial regions would there increase the temperature, in proportion as it diminished evaporation, which is so great a cause of cold. But it is very questionable how far the mean temperature, in high and temperate latitudes, would be reduced by an increase of land in the polar regions, where all is ice and snow already. And the fact of the mean temperature being lower in the southern hemisphere, in high and temperate latitudes where there is no land, than what it is in the northern, where there is a great amount of land, is at variance with his conclusion.

Of temperature as affected by wind, by atmospheric stillness, by clouds, by cities, by the falling of rain, &c.—At Glasgow, and usually in islands surrounded

by the ocean, the coldest winter weather occurs in the greatest absence of wind. The reason of this is, that the temperature of the atmosphere incumbent upon the surrounding ocean, is then much warmer than that over the land. Of course, wind blowing in any direction from the ocean during the coldest season of the year, raises the atmospheric temperature over the land. On continents, however, during the coldest period of winter, when the wind blows from a cold direction over a great extent of land, the temperature usually sinks as the wind increases in force. Thus the coldest weather during winter at Philadelphia in north latitude 39° 57′, is experienced when a strong wind blows from the north, or rather the north-west. In such cases, the temperature has sometimes been observed to sink as low as 14° under zero of Fahrenheit; and instead of being coldest when the weather is calmest, as happens in all insular climates, the thermometer sinks lowest when the wind from that quarter blows strongest. Besides, this wind, for reasons previously explained, is extremely dry relative to its capacity for moisture, and consequently, is felt to be piercingly cold. Indeed so much is this the case, that while it continues, the inhabitants of Philadelphia keep within doors as much as possible, and when they are under the necessity of going out in the way of business, and have to proceed in opposition to the atmospheric current, they generally run with their heads down, by way of sheltering the face.*

* In the beginning of the year 1835, a greater degree of cold was experienced in the United States of America, than had occurred within the recollection of the oldest inhabitants. In the

The greater steadiness of frost and cold weather during winter, and of warmth during summer, which is experienced on the continent of Europe, and in all inland countries, in comparison with what we are subjected to in Great Britain, is owing to the extreme temperatures during summer and winter, being more apt in our insular windy climate to be affected, and mitigated by clouds, and by atmospheric currents from the surrounding ocean, than in inland countries.

In this climate, the variations in the mean warmth of different summers, and the mean cold of different winters, is in a great measure to be ascribed to the greater or less amount of cloudy weather. During day and summer, when the temperature of the earth is upon the increase, clouds, by obstructing the solar rays before reaching the earth, reduce the mean temperature. On the contrary, during night and winter, when the temperature of the earth is upon the decrease, clouds, by obstructing the radiation of heat from the earth, raise the mean temperature. Hence, the reason that a cloudy wet winter is always a warm one; and on the contrary, that a cloudy wet summer is always a cold one, and produces a late harvest. And hence also the reason why the temperature never rises so much during day, nor sinks so much during night, when the weather is cloudy, as when it is clear.

At Glasgow, the mean diurnal range of tempera-

neighbourhood of Philadelphia, latitude 39° 57′, the thermometer fell at one time as low as 30 degrees below zero of Fahrenheit. This extreme cold was accompanied, and produced, by a strong wind, almost amounting in force to a hurricane, from the north-west.

ture exhibited by a thermometer suspended outside of a window, with a northern exposure, and about thirty feet above the ground, is from 7° to 8°. Sometimes it was observed to be as much as 20°; while at other times it did not exceed 1° or 2°.* It was greatest when the atmosphere was still, and the sky cloudless; and least when the wind was high, and the sky obscured by clouds. The reason of its being less when the wind was high, than when there was no wind, is to be ascribed to the surface of the ground being subjected to a greater diurnal range of temperature, than the air immediately incumbent; and to the diurnal range of temperature exhibited by the atmosphere becoming less, upon receding upwards from the ground. Consequently, during windy weather, the temperature of the lower atmospheric strata is prevented from rising during day, or from sinking during night so much as it would otherwise do, by the intermixture of the higher strata with the lower, which the aerial agitation during windy weather occasions. The reason why clouds diminish the diurnal range of temperature was explained in the preceding paragraph.

In large towns, such as Glasgow, and especially in their more central parts, the mean temperature is usually from two to five degrees higher, than what it is in the surrounding country a few miles distant. This is obviously owing, partly to the heat evolved during the combustion of fuel in large towns, and partly to the heat evolved by so many human beings congregated together, whose bodies are kept at the

* The above statements are exclusive of variations resulting from a change in the direction of the wind.

constant temperature of 96 degrees, by the chemical process of respiration.

The falling of rain or hail, especially in warm climates, or in summer in temperate latitudes, is usually observed to produce a sudden depression of temperature. This is owing to the rain bringing down a portion of the coldness which it has acquired, at the altitude at which it was formed into drops. The sudden reduction of temperature, which is observed immediately to succeed the heavy shower of rain or hail which terminates a thunder-storm, and which the peasantry ascribe to the fire being taken out of the air by the thunder, is to be attributed to the above cause, aided perhaps by the cooling influence of evaporation from the then watered surface of the ground.

On ascending perpendicularly, the mean annual, and more especially the mean diurnal range of temperature is said to decrease. This arises from the variations of temperature which the atmosphere undergoes, being communicated upwards from the surface of the ground. Owing to the permeability of the air to calorific radiation, little or none of the solar heat is arrested till it reaches the ground. Here, therefore, it accumulates during day and summer, and from this surface of accumulation, by slow degrees, and in proportions which diminish with the distance, an increase of temperature is imparted to the subjacent terrestrial strata, and to those of the incumbent atmosphere. The temperature of the higher regions of the atmosphere is, however, subject to vicissitudes, independent of those which are slowly communicated upwards from the subjacent earth. Thus the temperature of

the atmospheric strata is augmented in the region where clouds float, by the evolution of heat which attends their formation. And on the contrary, the temperature of those same strata is reduced, by the absorption of heat which accompanies the dissolution of clouds by evaporation. The existence of clouds likewise augments the temperature of those atmospheric strata where they float, by the increase of temperature which they themselves acquire, and communicate to the surrounding air, in consequence of partially arresting the sun's rays during day, and the radiation of caloric from the earth during night.

Of the lowest and highest atmospheric temperatures hitherto observed, &c.—Fifty-five degrees under zero of Fahrenheit, which was observed by Captain Parry, at Melville Island, is the lowest authentic atmospheric temperature on record. Many instances of high temperatures are incidentally noticed by travellers; but it is difficult to say whether the temperatures alluded to be those of the atmosphere shaded from the reflected, as well as the direct rays of the sun, or not. At Benares, the thermometer is recorded to have stood at 110°, 113°, 118°. Burckhardt states, that during a simoom at Esne, in Upper Egypt, the thermometer rose in the shade to 121°, but he adds, the air seldom remains longer than a quarter of an hour in that state, or longer than the whirlwind lasts. At Sierra Leone, a thermometer placed on the ground has been observed to indicate a temperature of 138°. Humboldt gives many instances of the temperature at the surface of the earth, amounting to 118°, 120°, and 129°: on one occasion he found the temperature of a

loose and coarse granitic sand to be upwards of 140°, when a thermometer in the sun only indicated a temperature of about 97°.

We shall conclude the subject of temperature by remarking, that in consequence of the radiation of caloric from the earth during calm and clear nights, a greater degree of coldness is communicated to the incumbent atmosphere, according as the surface of the ground underneath is better fitted for radiating caloric ; and according also, as the radiation of caloric therefrom is less obstructed by trees, buildings, or other elevated objects, that partially obscure the view of the sky. Thus under the shelter of trees, or contiguous to stone walls, or other elevated objects, or on acclivities, the temperature of the incumbent atmosphere sinks much less during clear calm nights, than it does over level grass fields freely exposed to the view of the sky. This subject is particularly worthy of the attention of military men, in order to direct them during cold weather in selecting fitting localities for armies to repose in the open air during night. To obtain thorough information on this point, military men may be recommended to study the principles that regulate the radiation of caloric, (which may be found in all systems of chemistry,) and are particularly referred to Dr Wells' Essay on Dew, where those principles are practically illustrated by a copious detail of experiments and observations.

CHAPTER VIII.

ON THE CAUSES AND PRINCIPLES WHICH PRODUCE WINDS; AND WHICH REGULATE AND DETERMINE THEIR DIRECTION, VELOCITY, AND CHARACTERISTIC QUALITIES.

Preliminary observations explanatory of the cause, direction, and velocity of winds, so far as they result from differences in the temperature of the atmosphere.—If both the density, and the incumbent pressure of the atmosphere were every where the same at the level of the sea, and at all equal altitudes above it, it follows, according to the hydrodynamic principle of equal weights balancing each other, and of fluids of equal density having no tendency to displace one another, that none of those horizontal motions of the atmosphere denominated Winds, could take place. On the other hand, when such inequalities, at equal altitudes, from any cause whatever do arise, it in like manner follows, from the analogous principle of the impossibility of fluids remaining at rest when their equilibrium is disturbed, or when the density of equally elevated strata is different, which necessarily disturbs their equilibrium, that a horizontal motion of the atmosphere must result. Winds, therefore, in every case, whether at the level of the sea, or at any elevation above it, originate in simultaneous inequalities of atmospheric density, or simultaneous inequali-

ties of incumbent atmospheric pressure at corresponding levels, in different places. And, according to the principle of fluids in their motions, obeying the preponderance of pressure, the direction of the wind must always be from where the incumbent pressure is greater, to where it is less.

From the experiments of Gay Lussac, it appears, that air between the temperatures of 32° and 212° expands $\frac{1}{480}$th part of its bulk, for every augmentation of temperature amounting to one degree of Fahrenheit. Of course, for every increment of temperature, amounting to 5°, the density of the atmosphere diminishes in consequence of expansion, rather more than 1 per cent. Hence it follows, that atmospheric columns of different temperatures, and containing the same amount of air, will differ in height. And though they exhibit the same barometrical pressure* at the level of the sea, they will exhibit a different barometrical pressure at all equal heights above it. Simultaneous inequality in the barometrical pressure in different places at the level of the sea, or at equal elevations above it, is therefore the proximate cause of winds; and inequality in the temperature of the atmosphere at the level of the sea, or at equal elevations above it, is the chief cause of unequal barometrical pressure in different places.

Agreeably to the estimate of Gay Lussac, air expands about 1 per cent. for every increment of temperature amounting to 5°. Hence it follows, provid-

* By the term "barometrical pressure," the amount of incumbent atmospheric pressure, as estimated by a barometer, is always meant.

ed the barometrical pressure be the same, that the atmosphere, at different times and places, must vary considerably in height. Supposing the amounts of air to be the same over two portions of the earth's surface of equal extent, so that the barometrical pressure at the level of the sea in both, should be similar; it follows, upon the supposition that the atmosphere extends to the elevation of 45 miles, that for every increment of temperature which the one acquires over the other amounting to 11°, provided this difference of temperature extend to the summit of the atmosphere, the warmest portion should be about one mile more elevated than the other. Again, supposing that the mean annual temperature of the atmosphere at the poles is zero of Fahrenheit, and the mean annual temperature at the equator 85° of Fahrenheit, it follows, provided the barometrical pressure at the level of the sea in both places is the same, and provided also that a difference of temperature, corresponding to that at the level of the sea, extends in both places to the summit of the atmosphere, that the height of the atmosphere above the level of the sea at the equator, should, upon the same principle of calculation, be nearly eight miles more than at the poles. Accordingly, if we suppose the height of the atmosphere at the poles to be 45 miles, it ought to be nearly 53 at the equator.*

* The above estimates are given, not as ascertained facts, but in order to illustrate the point under consideration. As the mean annual and diurnal range of temperature decreases, according to Saussure, as we ascend in the atmosphere, it is probable, that the difference in the atmospheric temperature, at equal altitudes above

The result of the difference of elevation in the atmospheric columns, according to their different degrees of warmth, is, that the upper portion of the higher columns, in obedience to the force of gravity, begins to float over upon the top of those that are less elevated. But while this diminishes the height, and the barometrical pressure at the level of the sea, of the warmer columns, it correspondingly increases the height and barometrical pressure of the colder columns. Hence, while the upper portions of the warmer, and consequently more elevated columns, are floating over upon the top of those that are colder and less elevated, the lower extremity of the colder columns, in obedience to the preponderance of barometrical pressure, begins to move in the opposite direction; and by the greater density of their particles, insinuate themselves underneath, and slowly uplift the warmer and lighter columns.

Agreeably to the preceding observations, the most general cause of wind, is the gradual diminution in the mean annual temperature from the equator towards either pole; and the prevailing direction in which the upper half of the atmosphere moves, is from the warm towards the colder climate, viz., from the equatorial, towards the polar regions. And on the contrary, the prevailing direction in which the lower half of the atmosphere moves, is from the cold to

the level of the sea in different latitudes, also decreases on ascending perpendicularly. Hence it may be inferred, that the difference between the mean height of the atmosphere at the equator and the poles, and between other places which differ in temperature at the earth's surface, is greatly less than what is stated in the text.

the warmer climate; and accordingly, from the polar towards the equatorial regions.

Local winds in general result from greater local depressions, or augmentations of temperature, which the atmosphere undergoes over one district or country, beyond what it does over another adjoining. The atmosphere over the cold district becomes depressed in height relative to that over the warm district. Consequently, a current in the upper half of the atmosphere moves from the warm to the cold district, while, from the additional weight which the latter thus receives, a current in the half nearest the ground, is propelled from the cold towards the warm district. Hence, the prevailing, or regular direction of winds in the lower half of the atmosphere, (and it is only to this half we refer when not otherwise stated,) is from a cold towards a warm district or climate.

Since the prevailing movement of the lower half of the atmosphere from a cold towards a warmer climate, is a consequence of increased barometrical pressure over the colder latitudes, resulting from the previous movement of the upper portion of the atmospheric columns from the warm towards the colder latitudes, it might be expected, that the mean height of the barometer should increase from the equator towards either pole. The following results of observations made in different places in the northern hemisphere, with all the necessary corrections for insuring accuracy, while they confirm this opinion, exhibit a less difference than might have been anticipated, and lead to the belief that a counteracting influence, to which we will subsequently advert, exists:—

	Latitude.	Mean Barometrical Pressure.
Calcutta . .	22° 35′	29.776
London . .	51 31	29.827
Edinburgh . .	55 56	29.835
Melville Island . .	74 30	29.884

The above results show how small a difference in the mean barometrical pressure on receding from the equator towards the pole, is sufficient to determine the prevailing direction of the wind in the lower half of the atmosphere. Playfair says, " If the surface of the earth were wholly covered with water, so that there were no part of it more disposed than another to obstruct the motion of the air, or no part which had a greater capacity than another of acquiring or communicating heat, the air would probably circulate continually from the poles to the equator, and back again without any irregularity whatsoever."

Agreeably to the principle that the direction of the wind at every altitude above the level of the sea, is from where the barometrical pressure is greater to where it is less; the existence of two currents moving in opposite directions to each other, the one in the upper half of the atmosphere, and the other in the lower, can only be accounted for upon the supposition, that there is a plane intermediate between the two currents, where the atmosphere is subjected to an equal barometrical pressure in every direction; and consequently where there can be no wind. In accordance with this opinion it is obvious, that on ascending from the surface of the earth to this plane, the average preponderance of barometrical pressure

from a colder to a warmer climate, will gradually diminish, ti llit ceases altogether. And that beyond this plane, the preponderance of barometrical pressure will increase on ascending; and instead of being from a cold to a warmer climate, as it was underneath the plane of atmospheric stillness, it will now be in the reverse direction, viz., from a warm towards a colder climate. In general, therefore, the nearer the plane of atmospheric stillness, whether above or below it, the less should be the velocity of the wind; and clouds, the nearer they are to that plane, from being less under the influence of wind, should appear the more stationary.

Judging from the fact of the barometrical pressure at the level of the sea remaining nearly equal in all latitudes, it is evident, that the amounts of air transported in contrary directions by the upper and lower atmospheric currents, must be the same. And upon the supposition, that the velocity of these opposite currents are equal, it is inferred, that one half of the atmosphere must be above, and the other half below the plane of intermediate atmospheric stillness; and consequently, the mean height of this plane, (for it may be supposed subject to more or less variation,) must be about the altitude of 18,000 feet above the level of the sea.

The notion that the prevailing direction in which the upper half of the atmosphere moves is the reverse of the lower half, is founded chiefly on inferences, deduced from the difference in the mean temperature of different latitudes, in connection with the ascer-

tained expansibility of air by means of heat, and the nearly similar barometrical pressure in all latitudes.

Upon this point my opinion is somewhat at variance with that which is commonly entertained. When the wind in the lower half of the atmosphere blows from a cold towards a warm climate, such as is exemplified by monsoons, and sea and land breezes, there can be no doubt of the existence of an opposite current in the upper portions of the atmosphere. But in all cases where the wind in the lower half of the atmosphere blows from a warm towards a cold climate, we will subsequently endeavour to show, that this universally received opinion of the existence of an opposite current in the upper half of the atmosphere, is erroneous. Even in the cases of monsoons, and sea and land breezes, no evidence of the existence of an upper current moving in the reverse direction of the lower half of the atmosphere, has yet been obtained by observing the motions of the *cirri*, the most elevated of all clouds. But if the half of the atmosphere be surmounted at the height of 18,000 feet above the level of the sea; and if *cirri* sometimes make their appearance at an elevation of 25,000 feet, as some meteorologists have estimated; evidence of an upper current, if it exist at all, should be obtained by observing their motions.

The only fact that I have met with, which affords direct evidence that the upper half of the atmosphere moves in an opposite, or in a different direction from the lower, is the following:—During the eruption of a volcano in St Vincent, in the year 1812, ashes and sand ejected by the volcano were carried in dense

clouds as far as Barbadoes, on which island they fell to the depth of nearly three-quarters of an inch. Now Barbadoes lies about a hundred miles east, or rather a little to the north of east, of St Vincent, and the trade-wind blows so directly from the former to the latter island, that a passage from St Vincent to Barbadoes can only be effected by making a circuit of many hundred miles. It is evident, therefore, that the ashes and sand ejected from the volcano in St Vincent, must have been transported to Barbadoes by an upper current of air, moving in the opposite direction from the regular trade-wind below. By inspecting the relative positions of these islands, and the nearest mainland of South America, by means of a map, it will at once be perceived that the direction of the upper current, in the above case, is, like that of monsoons, and sea and land breezes, from a warm towards a colder climate, and is produced in a similar manner.

The velocity with which winds move must be proportional, after deducting the retardation caused by friction, to the amount of force which produces them. This force, as already stated, arises from the differences in the incumbent atmospheric pressure, to which different portions of atmosphere at the same degree of elevation in reference to the level of the sea, are simultaneously subjected. Besides, agreeably to the principle that determines the increase of velocity which bodies subjected to a constant pressure acquire, when the preponderance of pressure continues in one direction, and consequently, when the wind continues to blow from one point of the compass, the ratio in

which its velocity should increase in successive equal times, provided there was no counteractive resistance produced by friction, and no diminution of impulse, should be the same as that of a falling body, viz. the odd numbers, 1, 3, 5, 7, &c. It is obvious, however, that friction must increase with the velocity of the atmospheric current. And it is likewise obvious, upon considering the circumstances which give rise to inequalities in the incumbent atmospheric pressure at equal altitudes, that were an atmospheric current continuing to increase in velocity, according to the above, or any other ratio, it would soon restore the atmospheric equilibrium, and thereby annihilate the impulse by which it had been created.

There is another point regarding the velocity of winds that requires explanation. Though a given amount of inequality in the incumbent atmospheric pressure, (say equal to one inch of mercury in a barometer,) at corresponding levels, in different places, must give rise to a certain determinate force, yet the velocity of the current will depend upon the distance between the two places. If, for instance, the atmospheric pressure from one parallel of latitude, or of longitude, to another a hundred miles distant, should gradually diminish, so that the mercury in a barometer stood one inch lower at one extremity of the distance than at the other, it would give rise to an atmospheric current whose velocity would be immensely greater, than if the barometrical pressure only diminished a similar amount in a distance of 500 miles. Friction, which is the only circumstance that counteracts the velocity of atmospheric currents, would, in the latter

case, be about five times greater than it was in the former. In the one case, the force which we have supposed equal to an inch of barometrical pressure, would have to propel a horizontal atmospheric stratum of 100 miles extent, subjected, all that distance, to the counteracting friction of the surface of the ground, propagated upwards from one aerial stratum to another, and that of the upper half of the atmosphere propagated downwards from one stratum to another. In the other case, the same amount of force has to propel a horizontal atmospheric stratum 500 miles in extent, subjected, all that distance, to the counteracting friction of the ground, and that of superior atmospheric strata.*

* It need hardly be remarked, that the degree of counteractive resistance to the motion of the air, produced by friction, varies with circumstances. 1. It diminishes as we recede from the surface where the friction takes place. If we suppose each stratum of aerial particles subjected to an equal degree of propelling force, the velocity of the stratum nearest the stationary surface ought to be most diminished by friction. The second stratum, supposing it never to come in contact with the ground, would have its velocity retarded by friction upon the first. But as the motion of the first stratum is only diminished, and not entirely overcome by friction upon the stationary surface of the ground, friction will only retard that proportion of the velocity of the second stratum, which exceeds the velocity of the first; and that proportion of the velocity of the third stratum, which exceeds the velocity of the second, &c. Hence the reason why on the top of a hill, steeple, or other eminence, the velocity of wind is greater than it is near the surface even of level ground. 2. The influence of friction in retarding the velocity of atmospheric currents, must obviously increase with the unevenness of the surface upon which friction takes place. Hence in towns, where the houses break the force of the current, wind is

Before proceeding further we may here sum up the more important part of the previous observations:—

1. Winds in every case, whether at the level of the sea, or at any degree of elevation in the atmosphere, arise from simultaneous inequalities of incumbent atmospheric pressure at corresponding levels, in different places. Hence, an opposite current near the surface of the ground from what is indicated by the motion of clouds in the higher regions of the atmosphere, can only result from the incumbent pressure being reversed at these different degrees of elevation.

2. Winds at every degree of elevation in the atmosphere, uniformly blow in the direction soonest calculated to restore the atmospheric equilibrium, and therefore always from where the incumbent pressure is greater, to where it is less.

3. The velocity of winds increases with, and, were it not for counteraction produced by friction, would be exactly proportional to the amount of force which produces them, with the addition of the velocity acquired by the continuance of the force operating in

less felt than in the country; and in the country, less where there are trees, and other obstructing projections, than where the land is clear of woods and level. A surface of water seems to give less obstruction in the way of friction than the most level land. It might be thought that no surface can be more uneven than that of the ocean agitated by a storm: for though the elevations and depressions be small, compared to what they are on land, they are infinitely more numerous. Nevertheless, waves by their progressive movement, so accommodate themselves to the friction of the wind by which they are produced, that they give less obstruction to atmospheric currents than any stationary land surface, however level.

one direction. Hence, the greater the inequality of atmospheric pressure at corresponding levels in different places; the nearer these places are to each other, (so that the wind may be the less retarded by friction;) and the more extended the respective surfaces over which these inequalities of atmospheric pressure exist, (so that the wind may acquire its maximum velocity by continuing in one direction;) the greater ought to be the velocity of the wind; and *vice versa*.

Before proceeding to apply the previous principles to the explanation of the various winds observed to blow on the earth's surface, we may insert the following table:—

TABLE OF THE FORCE AND VELOCITY OF DIFFERENT WINDS FOR THE GRADUATION OF ANEMOMETERS.

Height of the column of water in Dr Lind's Anemometer.	Force on square foot in pounds avoirdupois.	Force on a square foot in pounds, ounces, and drams avoirdupois.			Feet in one second.	Miles in one hour.	Feet in one second.	Miles in one hour.	CHARACTER OF THE WINDS.
					Computed from Rouse's experiments.		Computed from Dr Hutton's experiments.		
		lb.	oz.	dr.					
0.0009515	0.005	0	0	1.280	1.43	1	1.63	1.11	Hardly perceptible.—*Rouse.*
0.0038050	0.020	0	0	5.120	2.93	2	3.26	2.22	Just perceptible.—*Rouse.*
0.0083732	0.044	0	0	11.264	4.40	3	4.84	3.30	
0.0133210	0.079	0	1	4.224	5.87	4	6.52	4.44	Gentle wind.—*Rouse.*
0.023	0.123	0	1	15.488	7.33	5	8.09	5.51	
0.025	0.130	0	2	1.280	7.55	5.14	8.33	5.67	A gentle wind.—*Lind.*
0.050	0.260	0	4	2.560	10.67	7.27	11.77	8.00	Pleasant wind.—*Lind.*
0.092	0.492	0	7	13.952	14.67	10.00	16.16	11.01	Pleasant brisk gale.—*Rouse.*
0.10	0.521	0	8	5.376	15.19	10.35	16.66	11.35	Fresh breeze.—*Lind.*
0.11	1.107	1	1	11.392	22.00	15 00	24.30	16.57	Brisk gale.—*Rouse.*
0.368	1.968	1	15	7.808	29.34	20.00	32.39	22.00	Very brisk.—*Rouse.*
0.5	2.604	2	9	10.624	33.74	23.00	37.26	25.40	Brisk gale.—*Lind.*
0.585	3.075	3	1	3.200	36.67	25	40.51	27.62	Very brisk.—*Rouse.*
0.84	4.429	4	6	13.824	44.01	30	48.60	33.13	High wind.—*Rouse*
1.0	5.208	5	3	5.248	47.73	32.54	52.70	35.93	High wind.—*Lind.*
1.146	6.027	6	0	6.912	51.34	35	56.69	38.65	
1.5	7.873	7	13	10.688	58.68	40	64.79	44.00	Very high.—*Rouse.*
1.9	9.963	9	15	6.528	66.01	45	72.89	49.69	Great storm.—*Derham.*
2.0	10.417	10	6	10.496	67.50	46.02	74.53	50.81	Very high.—*Lind.*
2.68	12.300	12	4	12.800	73.35	50	81.02	55.24	Storm or tempest.—*Rouse.*
3.	15.625	15	10	00.000	82.67	56.37	91.28	62.23	Storm.—*Lind.*
3.37	17.715	17	11	7.040	88.02	60	97.20	66.27	Great storm.—*Rouse.*
4.	20.833	20	13	5.248	95.46	65.08	105.40	71.86	Great storm.
4.08	21.435	21	6	15.360	96.82	66	106.92	74.79	Great storm.—*La Condamine.*
5.	26.041	26	0	10.496	106.72	72.76	117.84	80.10	Very great storm.—*Lind.*
6.	31.490	31	7	13.440	117.36	80	129.59	88.54	Hurricane.—*Rouse.*
6.	31.250	31	4	00.000	116.91	79.71	129.09	88.01	Hurricane.—*Lind.*
7.	36.548	36	8	12.288	126.43	86.20	139.65	95.21	Great hurricane.—*Lind.*
8.	41.667	41	10	10.752	135.00	92.04	149.07	101.63	Very great hurricane.—*Lind.*
9.	46.875	46	14	00.000	143.11	97.57	168.11	107.80	Most violent hurricane.—*Lind.*
9.36	49.200	49	3	3.200	146.70	100	162.04	110.48	Hurricane that tears up trees, and throws
10.	52.083	52	1	5.248	150.93	102.90	166.66	113.63	down buildings.—*Rouse.*
11.	57.293	57	4	11.008	158.29	107.92	171.72	117.08	
11.12	58.450	58	7	3.200	160.00	109	176.55	120.37	Observed by *Rochon.*
12.	62.500	62	8	0.000	165.34	112.73	182.57	124.47	

By the preceding table it appears, that what Dr Lind denominates a most violent hurricane, moves at the rate of $107\frac{4}{5}$ miles in an hour, and exerts a force of 46.875 lbs. avoirdupois on a square foot of surface presented to it. This, after all, is rather less than the force that would be produced by a difference of barometrical pressure, equal to two-thirds of an inch in the height of a mercurial barometer, in two contiguous places. When the barometer stands at 30 inches, the atmospheric pressure is nearly fifteen pounds on the square inch of surface. Of course, one inch in the height of the mercury is equal to the pressure of half a pound on the square inch of surface; and equal to 72 pounds on the square foot of surface; whereas, the force of the hurricane above-mentioned, is only equal to an atmospheric pressure of 46.875 lbs. on the square foot of surface.

Winds are usually divided into regular, periodic, irregular, and hot. Of these we shall treat separately in their order.

Of the Regular or Trade-wind.—The only wind classed under the head of regular, from its blowing in the same, or nearly the same direction throughout the year, is what is usually denominated the Trade-wind. This wind, with some few exceptions, extends to about the 30th parallel of latitude, on both sides of the equator around the globe. Its direction is from east to west, inclining to the north of east on the north side of the equator, and to the south of east on the south side of the equator.* The variations in its de-

* The direction of winds is always denoted by the point from

clination from due east towards the north, or south, seem to be somewhat determined by the parallel over which the sun is vertical. Thus, as the sun advances from the equator towards the northern tropic, the trade-wind on the south of the equator gradually blows more from the south of east; and on the contrary, when the sun advances from the equator towards the southern tropic, the trade-wind on the north of the equator blows more from the north of east. In short, the trade-wind blows from the east, and its deviations from this direction are towards the parallel of latitude where the sun is at the time vertical.

We formerly stated that the prevailing direction of the wind in the lower half of the atmosphere, is from the polar towards the equatorial regions. Now, the trade-wind is supposed to result from the combined influence of this prevailing direction of the atmospheric current, and the rotation of the earth upon its axis. At the poles the earth has no motion of rotation; but gradually in advancing from the poles to the equator, the rotatory motion of the earth from west to east increases. Accordingly, a north wind on the north side of the equator, and a south wind on the south side of the equator, blow from latitudes where the earth's rotation on its axis is slower, to where it is faster. But as this increased rotatory motion is only slowly communicated by friction to the atmo-

which they blow, and never from that towards which they blow. Thus a south-west wind means a wind blowing from the south-west; and when a wind is said to incline or decline towards the south of east, it means that it blows from a point to the south of east.

sphere, a wind from the polar regions is left behind, and consequently, assuming a direction somewhat contrary to the earth's motion on its axis from west to east, blows from the north-east on the north side of the equator, and from the south-east on the south side of the equator. The collision of these two currents from the opposite hemispheres, by neutralizing and destroying their respective northward and southward movements, causes the atmosphere within the 30th parallels of latitude, to assume the easterly direction described above, and which, from its uniformity rendering it susceptible of being taken advantage of for commercial purposes, has been denominated the Trade-wind.

For analogous reasons to those previously mentioned, it is supposed that as the atmospheric current from the equator towards the poles, in the upper half of the atmosphere, is blowing from latitudes where the rotatory motion of the earth on its axis is quicker to where it is slower, it must gradually get ahead of the earth's rotation. Consequently, instead of blowing from due south, it will assume a south-west direction on the north side of the equator, and instead of blowing from due north, it will incline towards the north-west on the south side of the equator.

The influence of the earth's rotation in modifying the direction of the wind, as stated above, also explains the reason for the greater prevalence of a north-east than of a north-west wind, and of a south-west than of a south-east wind, to the north of the 30th parallel of latitude.

The trade-wind has been by some ascribed to the

attractions of the sun and moon. Upon this point Playfair says: "They (the attractions of the sun and moon,) have no doubt a tendency to produce in the atmosphere an undulation backwards and forwards, like the tides which they cause in the ocean. It does not appear, however, that they could produce any continued progressive motion of the air, similar to that of the trade-winds. Their effects also are too minute to be perceived amid the action of so many more powerful causes."

There is no doubt that the tide, as exhibited in the Atlantic ocean, resembles an immense wave undulating westward and eastward. But be it recollected that its westward progress is interrupted by the American coast. Provided the ocean covered the whole surface of the globe, in the same manner as the atmosphere does, in place of an undulation moving westward and back again, as is exhibited in the Atlantic ocean, the two great waves composing the two tides on opposite sides of the earth, would continually move round the globe from east to west without any interruption. There is no doubt that the progress of the tides would still be in the form of an undulation; for it is not to be supposed that any current could ever be so rapid as to keep pace with them. In intertropical climates their progressive motion is about 1000 miles an hour. But as full tide does not take place in the open ocean till nearly three hours after the moon has passed the meridian, a greater body of water subjected to the moon's attractive influence would be constantly to the eastward, than what was to the westward of the meridian where the moon was vertical. Hence I con-

ceive, that the attractive force exerted upon the smaller body of water to the west of the moon, would not be sufficient to resist the impulse given to the greater body of water to the east of the moon, by the same attractive power, together with the additional impulse arising from the motion of the tides being always in one direction. And hence I infer, that a current in the ocean from east to west, which would be strongest in the equatorial regions where the moon is most vertical, would be generated. Upon similar principles I conceive, that the trade-wind may be partly owing to the attractions of the sun and moon, and partly to the cause previously explained. But how much of the effect is to be ascribed to the one cause, and how much to the other, I can form no opinion.

Of Periodic Winds.—The first of these we will notice is what are usually denominated Sea and Land Breezes. In all maritime or insular situations in warm climates, where the sun is nearly vertical, and accordingly, where it exerts a strong heating influence, the surface of the land becomes warmer during day, and in consequence of more rapid radiation, colder during night, than that of the ocean. The consequence is, that the atmosphere over the land, from participating in its excess of warmth during day, is expanded upwards, and gives rise to a current in the upper portions of the atmosphere from the land towards the sea; and this, in its turn, in accordance with the principles already explained, gives rise to a current at the surface of the earth, from the sea towards the land. During night, however, when the surface of the land becomes colder than that of the adjoining sea, the atmo-

spheric columns immediately incumbent upon the land, by participating in its coldness, become more depressed than those over the adjoining sea. Hence the upper portions of the latter float over upon the former. And in consequence of the additional weight thereby communicated to the atmosphere over the land, a current close to the earth's surface from the land towards the sea is produced.*

Sea and land breezes, as above explained, afford the best practical illustration of the causes which produce winds when their direction is regular, (by which, wind in the lower half of the atmosphere blowing from a cold towards a warm climate is meant,) and of the principles which regulate their direction and velocity. They occur in general in all maritime situations and islands within the tropics. The sea breeze commences usually about 10 o'clock, A.M., that being about the time of day when the atmosphere over the land has be-

* In explaining the nature of sea and land breezes, it is usual to say, that the air over the land, on becoming heated during day, rises; and that the colder air over the sea rushes in to fill up the vacuity. This explanation is to a certain extent incorrect. Air over the land (and this remark is applicable to air heated by whatever means,) does not rise because it is heated, nor in rising does it leave any vacuity underneath. The only reason why heated air rises, is because the particles of colder and heavier air, in consequence of approximating nearer to each other, and nearer to the surface of the ground, insinuate themselves underneath, and consequently uplift the warmer particles. In short, a warmer and specifically lighter atmosphere is uplifted by a colder and heavier one, just in the same manner as water poured into a vessel displaces, by raising or uplifting, the air from its bottom. And just in the same manner as that water would, in its turn, be raised and uplifted from the bottom of the vessel, by pouring mercury into it.

come sufficiently heated, and expanded upwards, to give rise to it. It continues increasing till about one o'clock, P.M., when the air over the land has acquired its highest temperature relative to that over the ocean. After this time, its force gradually diminishes, till it entirely subsides by three or four o'clock in the afternoon. From this period till a little after sunset, the temperature of the atmosphere over the land and adjoining ocean, is so nearly equal as to be incapable of producing wind of any perceptible velocity. Shortly after sunset, the air over the land, in consequence of the coldness induced by the radiation of caloric from the surface of the ground being propagated upwards, begins to be colder than that over the ocean. Accordingly, the land breeze, which, in insular situations, blows from the centre of the island in every direction towards the sea, commences and continues till about sunrise, when it also entirely subsides. From this time till 10 o'clock, A.M., when the sea breeze, as before described, commences, the temperature of the atmosphere over the land, and the adjoining sea, is so nearly equal as to be incapable of producing a breeze of any perceptible velocity. Such is the order in which the sea and land breezes, during the course of twenty-four hours, alternately succeed each other.

The force of the respective sea and land breezes varies with, and is proportional to, the difference of barometrical pressure simultaneously over the land and sea; and the difference of barometrical pressure results from, and is proportional to, the difference of atmospheric temperature simultaneously over the land

and sea. Hence the reason that, when either the sea or the land breeze commences, it does so very gently, and gradually increases till it reaches its maximum velocity, when the difference in the temperature of the atmosphere over the sea and over the land is greatest. And thereafter, its velocity gradually decreases, as the difference of temperature above-mentioned diminishes, till it entirely subsides.

The locality where the force of the sea and land breezes is greatest, is where the temperature of the atmosphere within a limited distance horizontally, undergoes the greatest change. This of course is about the boundary where the sea and land meet. The distance to which the land breeze is felt at sea, and at which the sea breeze is felt inland, increases and diminishes with the simultaneous difference of temperature of the atmosphere over the sea and land, upon which the existence and velocity of these respective breezes depend. The land breeze, when it first commences, is only felt to a very small distance from the shore; but gradually extends itself so as to be felt on some occasions, to the distance of eight or nine miles at sea. In like manner, the sea breeze at first is only felt near the shore, but gradually extends itself, with diminishing velocity inland, to a similar, or perhaps sometimes to a greater distance, before becoming altogether imperceptible.

Such are the causes and principles which produce sea and land breezes, and which regulate and determine their force, direction, duration, and the limits to which they extend. And it may be farther added, that in all quarters of the earth, whether by land or sea,

similar causes produce and regulate the force, direction, duration, and limits, of all breezes, resulting from simultaneous differences of temperature in neighbouring localities.

Of Monsoons.—The next class of periodic winds of which we mean to treat, are those denominated Monsoons, or Season-winds, as the term implies. The following facts communicated by the celebrated Dr Halley, comprise almost all that is known respecting these winds:—

In that portion of the Indian ocean, lying between Sumatra and the African coast, and from 3° of south latitude to the Asiatic coast, including the Arabian sea and the Gulf of Bengal, the monsoons blow from the north-east from September to April, which is a little too northerly for the general direction of the trade-wind; but from April to September,* they change to the south-west; and more in with the land, to the west-south-west. During the former period the wind is more steady, and the weather less liable to sudden changes.

The explanation usually given of these opposite monsoons is the following:—When the sun, by the middle or end of April, has advanced considerably to the north of the equator, the surface of the land along the southern parts of Asia, within the boundaries described, begins to be warmer than the surface of the Indian ocean. This continues till some time in September, when the surface of the Indian ocean, in con-

* According to other accounts, the south-west monsoon does not commence till about the latter end of May or beginning of June.

sequence of the southern declination of the sun, begins to be warmer than that of the land, and so continues till April. Hence, in conformity with the principle which regulates the direction of the winds, as described when treating of sea and land breezes, the atmospheric current in the lower half of the atmosphere blows from where it is colder to where it is warmer. And accordingly, from the Indian ocean towards the land from April to September; and from the land to the Indian ocean from September to April. In both cases, agreeably to the principles explained when treating of sea and land breezes, and which need not be repeated, it is supposed that the upper portion of the atmosphere is moving in an opposite direction from the lower.

The reason why the monsoon, from the end of April to September, blows from the south-west instead of due south, is to be ascribed to the rotatory influence of the earth. A southerly wind to the north of the equator, is blowing from where the rotatory motion of the earth is quicker to where it is slower. And as the atmospheric current, in its progress northwards, only loses its greater rotatory velocity by slow degrees, it gradually gets ahead of the rotatory motion of the earth from west to east. And accordingly, instead of blowing from due south, it blows from the south-west.

On the contrary, when the monsoon blows from the land, from September to April, it blows from where the rotatory motion of the earth is less to where it is greater. Hence, in its progress southward, it is left behind the rotatory motion of the earth, and blows

from the north-east instead of the north, for the same reason as was assigned for the north-east direction of the trade-wind to the north of the equator.

The reason why the wind is less steady, and the weather more subject to sudden changes, from the end of April to September, than what it is during the continuance of the opposite monsoon, from September to the end of April, is to be ascribed to the influence of a vertical sun, during the former period, in producing what is called the rainy season. In the fourth chapter we had occasion to explain how vicissitudes of temperature, in neighbouring localities, are produced by partial showers; and how these occasion local disturbances, and temporary variations, in the direction of the winds.

Upon similar principles to those explained, when treating of sea and land breezes, and which we need not here repeat, the force of the south-west monsoon is felt strongest on land, and extends itself farthest inland, at the time when the difference between the temperature of the land and ocean becomes greatest; and *vice versa*. And the calms and variableness in the direction of the winds, which frequently occur for some time previous to the change of the monsoon, is to be ascribed, partly to the difference of temperature then existing over the land and adjoining sea, being so inconsiderable as to be incapable of giving any determinate direction to the winds; and partly to the influence of sea and land breezes, and other local causes, which, in the absence of those of a stronger and more general nature, begin to be felt.

Another of these monsoons is observed to take place

between the island of Madagascar, and the coast of Ajan, north of the equator. In that tract of sea, from April to October, the wind blows with a steady breeze about S.S.W.; but, from October to April, it resumes the general direction of the trade-wind, and varies from N.E. to E.N.E.

By inspecting a map it will be seen, that, in the portion of the Indian ocean above described, the monsoon, from S.S.W. from April to October, blows in what we have already described as being the regular direction of the wind, viz. from a cold towards a warm climate. This point, therefore, requires no further explanation. From the month of October to April, the temperature of the most southern and most northern latitudes included in the portion of the Indian ocean above described, is about equal. Hence, the cause that produced the monsoon in the opposite half of the year has ceased to exist; and, accordingly, the trade-wind resumes its regular direction.

A monsoon, of a less constant character, occurs in the Chinese seas, extending from Sumatra to Japan. The periodical winds in this tract, seem to be greatly influenced by the local and periodic differences in the atmospheric temperature over the land and the sea, produced by the large islands which bound it on the south, particularly Java, Borneo, and perhaps we may add New Holland. Their prevailing direction, from October to May, is from north to south, inclining a little westward.

The prevailing direction of this season-wind, over the extensive tract of sea above described, being, like those previously accounted for, from a cold to-

wards a warm climate, requires no farther explanation.

Under the head of Periodic winds we may notice those denominated Etesian and Ornithian; so called from its being observed that birds of passage take advantage of them, to assist them in their flight from one clime to another.

Of the Etesian Wind.—This wind, which blows from north to south, prevails very much over the continent of Europe, and particularly in those southern countries which form the northern boundary of the Mediterranean. It commences about the summer solstice, and continues usually for about six weeks without interruption. The direction of this periodic wind being, like all those previously accounted for, from a cold towards a warm climate, requires no further explanation.

Of the Ornithian Wind.—This wind commences about the beginning of March, and blows, with occasional interruptions, from the south-west, for five or six weeks. It prevails over the eastern portion of the Mediterranean, and sweeps over Greece and Macedonia. The cause assigned for this wind, is the melting of the snow on the mountains in the northern parts of Africa.

In general it may be remarked, that, upon the approach of summer in temperate latitudes, the melting of snow deposited during winter upon ranges of elevated mountains, has a tendency to give rise to diverging currents of cold air in every direction. Owing to the solar heat being absorbed by the melting snow upon the approach, and during the continuance of

summer, the atmosphere immediately incumbent upon the mountains, is partly cooled, and partly prevented from obtaining that accession of warmth during day, which it would otherwise then acquire. The consequence is, that the atmospheric columns over the mountains are condensed, and depressed in height, relative to those incumbent on the surrounding districts. Hence the summits of the latter float over upon those of the former, and the additional barometrical pressure thus communicated to the air over the mountains, causes currents near the surface of the earth to diverge from them in every direction. In the neighbourhood, therefore, of all extensive mountain ranges covered with snow, with their intermediate valleys consisting of glaciers, such as in the Alpine regions of Switzerland and the Tyrol, the wind, except when overcome by some stronger and more general cause, may be expected to blow from the mountains, during the whole period that the melting of the ice and snow is going on.

The prevailing winds in various quarters, which may, perhaps, with more propriety be classed under the head of regular than periodic, are such as are produced by difference of temperature, and blow from a cold towards a comparatively warm climate. Such winds admit of an obvious explanation, in consequence of their direction being in accordance with the causes and principles which produce and regulate the course of winds in general. Thus, according to the accounts of those who have recently visited very high latitudes in the northern hemisphere, the prevailing direction of the wind is there from the north; its variations

being chiefly confined within the north-east and north-west points of the compass. Again, along the northern coast of Africa, bounded by the Mediterranean, the prevailing direction of the wind throughout the year is also from the north. In both these cases, the prevailing direction is from a cold to a warm climate, and therefore in accordance with the principles already explained which direct the course of winds in general. In like manner, over the Atlantic, within 300 miles of the African coast, and especially in the warmer latitudes, the wind, instead of blowing from east to west, as is usual with the trade-wind, blows in the contrary direction, viz. towards the coast of Africa. This is usually ascribed to the great heat of the atmosphere in the interior of Africa, compared to that over the Atlantic ocean in corresponding latitudes. Of course this direction being on that account from a cold to a comparatively warm climate, the explanation is the same as that already given of similar cases.

Of Irregular Winds.—The winds which may be classed under this head prevail generally in all climates between the 30th parallels of latitude, and the poles. They also prevail, less or more, in intertropical climates during what is called the rainy season. They obey no fixed laws, either with regard to their velocity, or the periods of the year when they occur. But what chiefly distinguishes them, is their uncertain and variable nature, blowing sometimes from one direction, and sometimes from another; and as frequently from a warm towards a colder climate, as in the opposite, and more regular direction. Such winds, therefore, can never be predicted nor depended upon; and

do not admit of an explanation upon the principle, that atmospheric currents are wholly produced by variations in the temperature of the atmosphere.

We shall proceed to notice those irregular winds to which we are most subject in this island, with a view to introduce such explanatory observations, as appear to be applicable not only to them, but to irregular winds in general.

In temperate climates north of the 30th parallel of latitude, the prevailing direction of the wind over the Atlantic ocean, and the western shores of Europe, is from the west, and south-west. That this is the case, is evident from comparing the average length of time, taken by vessels in sailing from Great Britain to the United States in North America, with that which they occupy in returning. Thus, twenty-five days may be about an average passage from New-York to Liverpool; whereas, thirty-five days is about an average passage from Liverpool to New-York. The only reason assigned for this fact, and it is an evasion rather than an explanation of the difficulty, "is, that a current of air, having that direction, seems to be necessary to restore the equilibrium of the atmosphere, which is so incessantly disturbed by the action of the trade-winds."

In like manner, the fact of all the strongest winds experienced in Great Britain during the winter half of the year being from the south-west, that is, coming from a warm towards a colder climate, is found by meteorologists to be of equally difficult explanation.

By way of explaining the above, and similar cases

of irregularity in the direction of the winds, we submit the following observations.

Near the beginning of the present chapter, we gave a statement of the mean height of the barometer in four different places, from Calcutta, in north latitude 22° 35′, to Melville Island, north latitude 74° 30′. By that statement it appeared, that the mean height of the barometer increased from the equator towards the pole so very slowly, that the difference between the two extreme latitudes where the observations were made, amounted to little more than the tenth of an inch. Upon this result we remarked how small a difference in the mean barometrical pressure, is sufficient to determine the prevailing direction of the wind in the lower half of the atmosphere, from the polar towards the equatorial regions.

Agreeably to the principle, that the direction of the wind is always from where the barometrical pressure is greater, to where it is less, it follows, that its prevailing direction must be from where the mean barometrical pressure is greater to where it is less. Now, all we propose, in endeavouring to account for the prevailing direction of the wind in Great Britain, and along the western shores of Europe, being from the west and south-west, is to assign a plausible reason for the mean height of the barometer being greater, be the difference ever so small, in the direction from whence the wind blows, than what it is in the climates towards which it blows.

In our first chapter we explained the reasons why the mean hygrometric state of the atmosphere, was considerably drier than the point of saturation. It

was also there mentioned, that when the wind blew from an extensive tract of land, and also when it blew from a cold towards a warm climate, it became much undersaturated. On the contrary, when it blew from the ocean, and from a warm towards a colder climate, it was generally either fully saturated with moisture, or very little under the point of saturation. Now, it is chiefly from the Atlantic, and by means of the prevailing west and south-west winds, for which we are now endeavouring to account, that Europe, and even the western and northern parts of Asia, are supplied with all that moisture which is returned to the ocean by rivers. Hence it follows, that the barometrical pressure of the atmosphere, in its progress over the land, must diminish, according to the weight of aqueous vapour precipitated to the earth, and returned to the sea by rivers. On the other hand, an increased barometrical pressure over the Atlantic, so as to occasion a wind from the west or south-west along the western shores of Europe, may arise in circumstances such as the following. Let us suppose the wind to blow from a northern direction, that is, from a cold to a warmer climate, and particularly if a west or north-west wind blows over upon the Atlantic from the North American continent, (which is of frequent occurrence,) the atmosphere brought by such winds, is at first greatly undersaturated with moisture. The supply of humidity, however, which it soon receives by evaporation from the surface of the Atlantic, is neither more nor less than an augmentation to the amount of atmosphere, and which necessarily increases its barometrical weight. This I conceive gives rise

to an atmospheric current towards Europe, where its eastern direction is farther assisted, by the diminution of atmosphere, and accordingly of barometrical weight, which it sustains, in consequence of its humidity being partly precipitated to the earth, and returned to the sea by rivers.

Upon similar principles, the great force of south-west winds experienced in Great Britain, especially during winter, may be ascribed to the diminution of barometrical pressure which such winds undergo, in consequence of the great amount of rain precipitated during their north-east progress. Such, in my opinion, are the causes which render winds from the west and south-west more prevalent, and on an average stronger, especially during the winter season, over the Atlantic ocean to the north of the 30th parallel of latitude, and along the western shores of Europe, than from any other direction.

Similar causes to those above stated may be supposed to render winds from the ocean, and from inland seas in all quarters of the earth, towards the land, more prevalent and stronger than what they would otherwise be. And hence the preceding observations explain the chief cause of irregular winds, meaning thereby, winds which blow from a different direction than from a cold to a warm climate.

After reflecting upon the phenomena presented by aerial currents, the conclusion to which I have come is, that the two primary causes which disturb the atmospheric equilibrium, and occasion winds, are, 1*st*, Simultaneous inequalities in the temperature of the atmosphere at similar altitudes above the level of

the sea; and 2*d*, Unequal augmentations and diminutions in the amount of atmosphere in different localities, occasioned by unequal amounts of aqueous vapour being simultaneously added to the atmosphere by evaporation in different localities; and by unequal amounts being simultaneously withdrawn from the atmosphere, and precipitated to the earth, in different places, in the forms of rain, snow, hail, &c. The former of these may be regarded as the great cause of regular and periodic winds; while the latter, by disturbing that regularity, is the chief cause of irregular winds of every description.

Another cause of irregularity in the direction of the winds is reaction. It may be easily conceived that great velocity given to the atmospheric current by any cause, such, for instance, as the falling of a great amount of rain along the western shores of Europe, during a south-west wind, in the winter half of the year, will occasion an accumulation of the atmosphere, so as to give rise to increased barometrical pressure, in the eastern parts of Europe, and western parts of Asia, beyond the boundaries where the falling of rain, at least in any considerable quantity, extends. The consequence of this will be, that reaction will take place, and the wind, instead of continuing to blow from the south-west, will shift to the opposite direction, and blow from the north-east. This wind not improbably returns to the Atlantic ocean nearly the same identical atmosphere, deprived, however, of a large proportion of its moisture, which formerly came from that quarter. The same process as that which has been already described, will, in such circumstances,

be again renewed. The cold dry atmosphere from the north-east, will be gradually heated and replenished with humidity by evaporation from the surface of the Atlantic. The supply of humidity which the atmosphere thus receives, will augment its volume and increase its barometrical weight; and thus will ultimately give birth to a west or south-west wind blowing towards the shores of Europe. A similar diminution in the atmospheric pressure, occasioned by the descent of rain in the progress of the atmosphere from a warm to a cold climate, will increase its velocity. And a similar accumulation of air, and an increased barometrical pressure, will take place in those eastern regions, beyond where the rain reaches in any quantity, and this will ultimately again produce reaction, as before described. The reason why the velocity of the east and north-east winds is not nearly so great as that of the west and south-west, is, that the former is not usually assisted by the diminution of barometrical pressure, occasioned by the falling of rain, like the latter.

Such I conceive are the causes why the most prevalent winds in this country, and along the western shores of Europe, are from the south-west and west; and the next most prevalent, from the north-east and east: and why the former are usually much stronger than the latter. And such are the reasons, why the change of wind from one of these directions to the opposite, and back again, is of such frequent occurrence.

Reaction arising from atmospheric accumulation, may also be expected to give a contrary direction to

the wind in every case, where a diminution occurs in the difference of temperature in different latitudes, which has previously given birth to a wind of a determinate velocity. Changes in the direction of the wind arising from this cause, in connection with the different degrees of rapidity with which different neighbouring localities, and different latitudes, increase and diminish in temperature, are of frequent occurrence in most parts of the earth, during the sun's progress to the north and south of the equator. And it need hardly be remarked, that the accumulations of air in particular regions, not only produce that irregularity in the direction of the wind which we call reaction, but causes further irregularity, by giving rise to diverging currents in every direction. In like manner every rarefaction of the atmosphere in any particular district, whether arising from increased heat, or sudden and great precipitations of moisture in the form of rain, occasions further irregularity in the direction of the winds, by causing converging currents in every direction; and this ultimately again produces reaction.

In the 3d chapter, we stated our objections to the commonly received opinion, that the upper half of the atmosphere moves in all cases in the opposite direction of the lower; and advanced the hypothesis, that, when the wind in the lower half blows from a warm towards a cold climate, as is exemplified in the case of a south-west wind during winter, blowing from the Atlantic towards the shores of Europe, no opposite current can simultaneously exist in the upper half of the atmosphere.

In the case of a wind in the lower half of the atmo-

sphere blowing in the regular direction, from a cold to a warm climate, such as is exemplified by sea and land breezes, and monsoons, the wind near the earth's surface from the cold locality, is a consequence, and a concomitant of the increased barometrical pressure, occasioned by the previous commencement, and continuance of a current in the upper half of the atmosphere, from the more elevated aerial columns over the warm locality. But when the wind in the lower half of the atmosphere blows from a warm towards a cold climate, the atmospheric columns over the latter must not only contain less air, (in order to account for the direction of the wind near the earth's surface,) but must be less elevated, in consequence of being colder than what they are over the former. Hence, according to pneumatical principles, when the wind blows from the west or south-west during winter towards the shores of Europe, it is physically impossible that a contrary current in the upper half of the atmosphere from the east or north-east can simultaneously exist; and the same observation is applicable to all other cases where the wind in the lower half of the atmosphere blows from a warm towards a cold climate. The atmosphere, like all other fluids, is subject to the laws of gravity; and it is just as impossible that the upper half of the atmosphere can blow from any district where the atmospheric columns are colder, and less elevated, and contain less air, to where they are warmer, and more elevated, and contain more air, as it would be for a river to flow up a hill.

Reasoning according to dynamical principles, it may be inferred, that, when the wind blows from a

warm towards a cold climate, the whole air from the earth's surface to the summit of the atmosphere must move simultaneously in the same direction. But as air, like other elastic fluids, becomes denser in the ratio of compression, I infer, that in such circumstances, the force that produces wind, viz., the superiority of atmospheric pressure in one place over another at an equal altitude above the level of the sea, increases as we approach the earth's surface. Hence, except for the counter influence of friction on the earth's surface, and which must be propagated upwards with diminishing effect from one aerial stratum to another, the velocity of the wind should decrease upon receding perpendicularly upwards from the level of the sea. On these grounds, together with the fact of moisture being abstracted in the form of rain only from the aerial strata within a limited distance of the level of the sea, I am disposed to think, that in most cases, the velocity of the atmospheric current is nearly equal for a considerable distance, such as perhaps for a mile or two above the earth's surface; but that beyond that altitude, its velocity gradually diminishes. And as was formerly stated, this opinion is confirmed by the great velocity with which clouds suspended at a low altitude apparently move, when compared with those at a greater elevation, even after an allowance (not estimated, however, with sufficient scientific accuracy,) is made for the optical illusion produced by the greater distance of the latter.

Thus we see there are two principal varieties in the movements of the atmospheric columns, viz., one in which their upper extremities move in the opposite

direction of their lower extremities; and another where the whole columns move in the same direction, but with diminishing velocity from the earth upwards, or perhaps with diminishing velocity upwards beginning at the altitude of a mile or two above the level of the sea. The former of these cases occurs when the wind, in the lower half of the atmosphere, blows from a cold towards a warm climate or locality; and is exemplified by sea and land breezes, and monsoons. The latter occurs when the wind, in the lower half of the atmosphere, blows in the direct, or in nearly the direct line from a warm towards a cold climate. And it does not matter whether this direction of the wind be the result of reaction, or of additions made to the atmosphere by evaporation of moisture from a watery surface underneath.

Besides the two preceding varieties in the movements of the atmospheric columns, others which must occur in certain circumstances might easily be deduced. For instance, supposing a wind about the end of April or October blowing in this climate from the west towards the shores of Europe, that is, blowing along the same parallel of latitude at a time when the atmospheric temperature over the land and ocean, at the same distance from the equator, is about equal. In this case, the wind from the west is occasioned by a preponderance of atmospheric pressure near the earth's surface over the Atlantic, when compared with the atmospheric pressure over Europe. But though the atmospheric pressure for many degrees both to the south and north of the place of observation be the same at the level of the sea, still, owing to the greater

warmth and elevation of the atmospheric columns lying to the south, and consequently to the circumstance of the warm columns containing a smaller amount of air within a given distance of the earth's surface, than the cold columns, the preponderance of atmospheric pressure at equal altitudes above the level of the sea, must veer more and more round to the south of west, upon ascending perpendicularly. Hence, though the wind blow directly from the west at the surface of the earth, it will blow, in such circumstances, more and more from the south of west, the higher we ascend in the atmosphere.

It might also be demonstrated, that a mountain range would, in certain circumstances, modify, or even reverse, the current in the upper portion of the atmosphere. For instance, suppose the trade-wind within the tropics meeting with a range of mountains, such as the Andes, running at right angles to the direction of the wind, a current in the upper portions of the atmosphere would be generated in the opposite direction. The principle according to which this result is deduced is the following. The trade-wind blowing constantly from the east, upon being partially interrupted by the mountain range, gives rise to a permanent accumulation of air, and a consequent greater elevation of the atmospheric columns on the windward side of the mountains. Now, though the increased barometrical pressure thus produced, may not be sufficient altogether to overcome the force and acquired velocity of the trade-wind near the earth's surface, still as the force and velocity decrease upon ascending perpendicularly, an elevation will be at

length reached, when the preponderance of barometrical pressure occasioned by the interruption of the wind, and consequent accumulation of air, will not only be overcome, but an opposite current, blowing from west to east, will be generated.

Upon similar principles the direction of the wind in the lower half of the atmosphere is more or less altered, as if it were by reflection, upon meeting with an elevated mountain range, running in any line between what is transverse and parallel to that of the wind. In this case, the interruption of the atmospheric current by the mountains, causes accumulation of air, and slightly increased barometrical pressure on their windward flanks. And this increased barometrical pressure, instead of checking the atmospheric current, merely causes it to assume a reflected direction, at an angle corresponding to that of incidence. It is said that a south-west wind, upon meeting with the very elevated Himalaya mountains, forming the northern frontier of India, is reflected in this manner.

Other varieties and alterations in the direction of the winds dependent upon local causes, might be deduced in a similar manner. Those already given are, however, sufficient to explain the principles upon which the deductions are made. Let it only be recollected, that every superior elevation of the atmospheric columns over any district, such as may result from superior warmth, gives rise to a current in the upper portions of the atmosphere, from that district towards colder localities. Let it be also recollected, that, near the earth's surface, the direction of the wind, at any time and place, is the conjoint result of acquired

velocity, and of the preponderance of atmospheric pressure in one quarter of the horizontal circumference, over the opposite. Of course, any local cause which occasions increased accumulation of air, and consequently increased barometrical pressure over any district or portion of the earth's surface, such as superior coldness, increased evaporation, or interruptions by mountains to the progress of the wind, exerts more or less influence in originating wind from that quarter; or in the case of wind blowing towards that quarter, in reflecting it, and giving it a new direction away from the district where increased barometrical pressure exists. On the contrary, any local cause which occasions diminished barometrical pressure, such as superior warmth, or an unusual abstraction of aqueous vapour from the atmosphere in the form of rain, has a tendency to originate currents towards that quarter; and where any atmospheric current previously exists, exerts an influence in turning it aside from its previous direction towards that quarter, as if it were thereby attracted.

Those very local squalls, or gusts of wind, which are sometimes observed to issue out of particular glens or valleys amidst a mountainous country, and which, on the sea-coast, are so much dreaded by mariners, are to be ascribed to the influence of the mountains in obstructing the general progress of the atmospheric current. The obstruction thus presented, causes more or less atmospheric condensation and compression, and this compression, by giving the air increased elastic force, causes it to issue from those glens and narrow passages through which its course

is directed, in the form of a squall or violent gust of wind.

The reason why rising grounds, or hills, lying to windward, generally afford little or no shelter from the atmospheric current, especially if their acclivity be very gradual, is owing to the increased atmospheric pressure, and reactive force, which the wind acquires upon reaching the summit of the hill or rising ground.

After the explanation previously given of the cause of the prevalence of south-west winds along the western shores of Europe, it need hardly be repeated, that inequalities in the amount of moisture evaporated from different portions of the earth's surface, and which vary in relation to each other at different times, (being in reality equivalent to unequal creations of atmosphere,) necessarily give rise to unequal barometrical pressure in different places, and is, therefore, a cause of irregular winds. On the other hand, unequal precipitation of moisture from the atmosphere in different places, whether in the form of rain, hail, snow, or dew, and which in reality is equivalent to unequal diminutions of atmosphere, necessarily occasions unequal barometrical pressure, and likewise produces irregularity in the direction of the winds.

The general principle applicable to winds arising from the above causes, is, that their direction, unless counteracted by difference of temperature, or some stronger or more general cause, should, in the one case, be from where evaporation, or the augmentation of atmosphere, is going on more rapidly, to where it is proceeding more slowly; and in the other, from where the amount of rain is less, to where it is greater.

Or by compounding these two cases, the direction of the wind, if freed from the influence of all other causes, ought to be from where evaporation, or the augmentation of atmosphere, goes on most copiously, to where the diminution of atmosphere, or of atmospheric weight, by the precipitation of moisture in the form of rain, proceeds with greatest rapidity. Hence, if no other causes of wind existed, its prevailing direction ought to be from the ocean and a warmer climate, towards a mountainous country situated in a colder latitude. The former is where the amount of moisture evaporated, is greatest relative to that which is precipitated; the latter is where the greatest amount of rain falls, relative to the quantity of moisture evaporated.

The circumstance of the addition to the atmosphere by evaporation of moisture, relative to its diminution by precipitation, being greater in warm than in cold climates, accounts for the increment in the mean barometrical pressure on receding from the equator towards the poles, being so small as was formerly stated. In reality, the natural direction of irregular winds, meaning thereby, winds occasioned by unequal evaporation and precipitation of moisture in different localities, if not influenced by other causes, is the reverse of winds resulting from difference in the atmospheric temperature in different places. The direction of the former is from a warm towards a comparatively cold climate, while that of the latter is from a cold towards a comparatively warm climate. These two causes of wind in some degree balance and counteract each other, each of them gaining the ascendancy in suc-

cession. And the prevailing direction of the wind in any place, and the degree of prevalence, is determined by the mean preponderance of one of these causes over the other.

The preceding observations partly explain the reason why clouds, during showery weather, are peculiarly directed towards, and along chains of mountains. The result here alluded to is, however, partly illusory, and partly real. Clouds appear to be directed toward mountains, partly in consequence of the influence of mountains in forming clouds during windy weather; and partly in consequence of the local direction given to the wind, by the local diminution of atmospheric pressure, that results from the greater abundance of rain which falls upon the mountains; and which the altered direction, and augmented velocity of the wind, farther contributes to increase.

The impetus given to the atmospheric current by the diminution of barometrical pressure which attends the falling of rain, also explains the reason why windy weather is more prevalent, and the winds generally stronger, in showery than in dry weather; and also, why they are stronger in showery weather among and in the neighbourhood of mountains, where the greatest amount of rain falls, than in champaign, low-lying countries.

Clouds, as we remarked when treating of their suspension in a former chapter, displace a weight of atmosphere equal to their own. It is therefore not their formation, but their dissolution in the form of rain, which diminishes barometrical pressure. Besides, the falling of rain, particularly when in partial

showers, gives rise to irregular and variable winds, not only by the local diminution of atmospheric pressure which it occasions, but also by its influence in reducing the temperature of the atmosphere, through which it passes in its descent to the earth. As this latter influence of rain was treated of at length in our fourth chapter, it need not be here repeated.

The irregularity and variableness in the direction of the winds within the tropics, during what is called the rainy season, is principally owing to the local and unequal diminutions of barometrical pressure, together with the irregular reduction of the temperature of the lower atmosphere, which the frequent descent of partial heavy showers of rain occasions.

The climates in which windy weather is most frequent, are those where vicissitudes of temperature are most sudden, and especially where those vicissitudes, in neighbouring localities, are most unequal. Thus, in far inland countries, where the atmospheric temperature is usually nearly equal for a great distance around, very little windy weather is experienced, in comparison with what occurs on continental coasts, where the atmospheric temperature over the land in the one direction, and over the sea in the other, is frequently very unequal. In like manner, in the Pacific ocean, owing to its great extent, and the sameness of temperature which accordingly exists, during all seasons of the year, to a great distance around, much less wind is experienced than in seas of smaller magnitude.

Upon analogous principles, in those seasons of the year when the atmospheric temperature is undergoing

the most rapid alteration, and which, in neighbouring localities, are always more or less unequal, high winds are most frequent, and their direction most variable. Thus, in temperate latitudes windy weather is of less frequent occurrence during summer, when the atmospheric temperature is much nearer equality for a great distance around, than what it is during winter. The high winds which are frequently observed to happen about two or three weeks after the vernal, and more particularly after the autumnal equinox, and which are denominated equinoctial blasts, are principally to be ascribed to the rapid and unequal alterations in the atmospheric temperature in different localities, which occur at these seasons of the year. And the greater strength of the blasts which occur after the autumnal than after the vernal equinox, is to be ascribed to the greater amount of rain that usually falls about the former period, when the temperature is declining, than about the latter, when the temperature is advancing. In like manner, in high polar latitudes, it has also been observed, that the winds are strongest, and most variable, during spring and autumn, when the atmospheric temperature is undergoing its most rapid alteration, and when, in different neighbouring localities, it becomes most unequal. On the contrary, during the height of summer, and also during the depth of winter, when the atmospheric temperature in those very high latitudes for a great distance around becomes nearly equal, there is almost no wind.

But to conclude this subject. When we observe the irregularity with which land and water, together with mountains, forests, cultivated and uncultivated

soils, are distributed and intermixed over the earth's surface;—and if we bear in mind the unequal augmentations, and diminutions of temperature, which they are simultaneously undergoing, during the alternate successions of day and night, and the different seasons of the year;—and when we at the same time recollect the other causes previously mentioned, which disturb the atmospheric equilibrium, the irregularity in the direction of the winds, which is greatest in those climates, and in those seasons of the year, when the temperature is most subject to sudden and great variations, is by no means surprising.

In certain localities, causes, which separately should occasion opposite currents, neutralize each other, and produce atmospheric stillness. Thus, between the meridians of Cape Verde and the eastermost islands of the groupe which bear that name, there is a zone 350 miles in breadth, in which there is almost no wind, except of the lightest and most variable description. Ships have here been known to be becalmed for whole months. It has been denominated the Rains on account of the great amount observed to fall; thunder is also here of frequent occurrence. The reason assigned for the want of wind in this quarter is, that it occupies a position where the trade-wind blowing towards the west, is neutralized and no more, by the cause previously assigned for the wind, which, beyond the eastern boundary of this zone, blows towards the heated shores of Africa. The reason of the great abundance of rain in this region, is not properly understood. It is possibly owing to the sinking down and intermixture of cold aerial strata, brought by cur-

rents from the north and south in the upper regions of the atmosphere, with the warmer strata underneath. And it is probable, that corresponding amounts of air are abstracted from this zone, to supply in part the currents which diverge from it to the east and west. The frequency of thunder here, is probably owing to the conjoint influence of the unusual prevalence of cloudy weather, and the rapid increase of temperature, and consequently of electrization, which the clouds undergo, by exposure to the rays of a vertical sun.

Calms in similar localities, and resulting from like causes, prevail under the equator, in the western hemisphere, between Cape St Francis and the Gallapagos islands. And we are informed by Humboldt, that the same sluggish state of the atmosphere, is experienced on the western shores of America, between 13° 30′ and 15° of north latitude, and 103° and 106° of west longitude, during the months of February and March. In the year which preceded that in which he visited those seas, a dead calm of twenty-eight days, with a want of water in consequence of it, forced the crew of a ship newly built at Guayaquil, to abandon a rich cargo of cocoa, and save themselves in their boat, by making for the land eighty leagues distant.

Of the Hurricane or Typhon.—The next irregular wind of which we mean to treat is the Hurricane. This, which is the most violent of all winds, assumes its most formidable aspect in the West Indies, the Isle of France, and the Indian ocean. In the West Indies, where we are best acquainted with its pheno-

mena, it occurs only during the rainy season; and most frequently in the month of August. It consists of furious wind, accompanied with thunder and lightning, and torrents of rain. Generally, in its most violent form, it does not last for more than two or three hours. Torrents of rain, however, accompanied with wind so violent as almost to be entitled to the name of a hurricane, sometimes continue in intertropical climates, for one, two, or even three days.

A vivid, though perhaps an embellished description of a hurricane, which occurred when Columbus was about to sail from Isabella island, is given by Washington Irving as follows:—"About mid-day a furious wind sprang up from the east, driving before it dense volumes of cloud and vapour. Encountering another tempest from the west, it appeared as if a violent conflict ensued. The clouds were rent by incessant flashes, or rather streams of lightning. At one time they were piled up high in the sky, at another they descended to the earth, filling the air with a baleful darkness more impenetrable than the obscurity of midnight. Wherever the hurricane passed, whole tracts of forests were shivered, and stripped of their leaves and branches, and those of gigantic size which resisted the blast were torn up by the roots, and hurled to a great distance. Groves were torn from the mountain precipices, and vast masses of earth and rock precipitated into the valleys with terrific noise, choking the course of the rivers. The fearful sounds in the air and on the earth,—the pealing thunder,—the vivid lightning,—the howling of the wind,—the crash of falling trees and rocks filled

every one with affright, and many thought that the end of the world was at hand. Some fled to caverns for safety, for their frail houses were blown down, and the air was filled with the trunks and branches of trees, and even with fragments of rocks carried along by the fury of the tempest. When the hurricane reached the harbour, it whirled the ships round as they lay at anchor, snapped their cables, and sunk three of them to the bottom, with all who were on board. Others were driven about, dashed against each other, and tossed mere wrecks upon the shore, by the swelling surges of the sea, which, in some places, rolled for three or four miles upon the land. The tempest lasted for three hours. When it had passed away, and the sun again appeared, the Indians regarded each other with mute dismay. Never, in their memory, nor in their traditions, had their island been visited by such a tremendous storm. They believed that the Deity had sent this fearful ruin to punish the cruelties and crimes of the white men, and declared that this people had moved the very air, the water, and the earth, to disturb their tranquil life, and to desolate their island."

Two causes have been assigned for hurricanes, but neither of them is by any means satisfactory. One of them is, that large quantities of hydrogen supposed to exist in the higher regions of the atmosphere, are united to the oxygen of the air, and suddenly condensed into water by means of electricity; and that the vacuity or great rarefaction of the atmosphere thereby occasioned, is the cause of the hurricane. This explanation we consider entirely chimerical.

For though hydrogen is one of the constituents of aqueous vapour, there is no evidence whatever that it exists in large quantities either as a separate gas, or as one that is mixed with the atmosphere, in its more elevated regions.

The other explanation of hurricanes is, that they are occasioned by "the sudden destruction of large portions of the atmosphere by means of electricity, and by the subsequent rushing of the surrounding air into the partial void which is thus formed." This explanation we also consider somewhat chimerical; for we have no evidence whatever of electricity having power to destroy any portion of the atmosphere. It is a maxim in chemical philosophy, that the annihilation of even the smallest particle of matter never takes place naturally, nor can be effected by artificial means. The term destruction, therefore, as applied to the atmosphere in the above quotation, can only mean, that its elements are condensed by the agency of electricity into liquids or solids, and precipitated to the earth. We know that aqueous vapour may be condensed into water and precipitated to the earth. But what liquids or solids are precipitated to the earth, in consequence of the condensation of oxygen, nitrogen, and carbonic acid gases, (for these seem also included in the phrase "large portions of the atmosphere,") is left unexplained.

It is probable that hurricanes, in their more violent forms, are occasioned by a favourable combination of those circumstances which produce wind in general. The chief of these is a sudden and widely extended simultaneous diminution of barometrical pressure,

produced by a sudden, simultaneous, and widely-extended heavy fall of rain, which is a never-failing attendant of the hurricane. The reason why the circumstance of the rarefaction being spread over a large surface increases the force of the wind, is owing to its setting in motion a greater amount of air in all directions around. A large vacuity is not so soon filled up as a small one. And a large amount of air set in motion, acquires velocity according as it is subjected to a constant pressure for a longer time. Besides, before reaction can commence, the impetus of a larger amount of air in motion has to be overcome. Of course, the aerial condensation, and the reaction of the hurricane is stronger, according as the previous rarefaction which gave the hurricane birth, is greater, and more widely extended. We formerly stated that clouds, in order to their suspension, must displace a weight of atmosphere equivalent to their own. Of course, when the very dense and widely-extended clouds, (which are also constant concomitants of hurricanes,) are suddenly and rapidly dissolved in rain, the barometrical pressure is not only thereby reduced in proportion to the weight of rain that falls, but the space in the atmosphere which the clouds previously occupied, is left void until filled up by the rushing in of air. This cause is farther assisted by the sudden reduction of temperature, and condensation, which the heated atmosphere beneath the clouds undergoes, in consequence of the rain bringing down the coldness which it had acquired, at the altitude where it was formed into drops. The sudden cooperation of these circumstances over a widely-ex-

tended surface, is sufficient to account for a great and extensive rarefaction of the atmosphere, which must necessarily occasion a sudden rush of air from all quarters around, towards the centre of rarefaction. And this, in my opinion, with the subsequent reaction, arising from the accumulation of the concentrated currents of air, constitutes the hurricane.

The circumstances in which hurricanes usually happen, are also favourable for the efficacy of the causes above assigned for their production. They are usually preceded by great warmth and atmospheric stillness, and by a low state of the barometer, which sinks much farther during their continuance. The previous low state of the barometer may be occasioned by the great heat expanding and elevating the atmospheric columns, so as to generate diverging currents of air from their upper portions towards colder regions. This circumstance, which, of itself, would ultimately produce reaction, and give rise to a contrary current near the earth's surface, is probably one of the combination of circumstances which tends to increase the fury of the blast. Again, hurricanes only occur in warm climates, and during the most sultry weather in the hottest season of the year. The great capacity of heated air for containing moisture, both in the invisible state, and in the visible form of cloud, accounts for the immense quantity of rain which falls in a short time during a hurricane. Besides, the previous atmospheric stillness favours the air in sustaining the utmost amount of humidity, both in clouds and in invisible solution, which, at any given temperature, it is capable of retaining; while the agitation of the atmo-

sphere during the hurricane produces the opposite effect, and consequently strengthens the blast. The clouds also, from the appearances previously presented, as well as from the thunderstorm which introduces and accompanies the hurricane, seem to be in a highly electrified condition. Owing to this additional circumstance, the air is enabled to suspend a much larger amount of aqueous vapour in the form of clouds. The vesicles of which these clouds are composed being all severally strongly charged with electricity, repel each other. Hence, they do not unite, until the vesicular condensation, arising from the great amount of vesicles of similar specific gravity, all pressing downwards to the same horizontal level, becomes much greater than it would otherwise be. So soon, however, as the electric fluid begins to be abstracted from the clouds in the form of lightning, the vesicles rapidly unite, and give rise to the torrent of rain which then commences; and which, aided by reaction arising from the previous low state of the barometer, which is farther increased by the descent of rain, is the chief cause of the hurricane.

Hurricanes are always accompanied by a very low state of the barometer, and the wind is frequently directed from every quarter, towards the point where the atmospheric pressure is least. They are commonly propagated to windward; that is, their influence is first felt at the place towards which the current flows, and is gradually extended in the direction from which it comes. This fact was ascertained by Dr Franklin in the case of a strong wind from the north-east, which occurred at Philadelphia in the year

1740. It commenced at Philadelphia at seven o'clock in the evening, and by comparing the various accounts which he received from the different places over which it passed, he found that it began about an hour later for every 100 miles towards the north-east.

From this fact it has been believed, that all winds are propagated in a similar manner to windward. This opinion, however, I conceive to be erroneous. When winds are produced by a sudden rarefaction of the atmosphere in any particular quarter, they will always be propagated to windward in the manner above described. But when they are occasioned by an accumulation, or condensation of the air, they will be propagated from the centre of accumulation to leeward. Thus, when the reaction of the hurricane occurs after the short interval of atmospheric stillness, the wind is propagated from the centre of accumulation to leeward, though the first beginning of the hurricane was propagated to windward. It is also observed, that, in those climates where sea and land breezes prevail, the commencement of the sea-breeze, urged on from where the preponderance of barometrical pressure is greatest, is seen, by the ripple on the water, advancing towards the shore, that is to leeward. It is probable, however, that, in most cases, previously to the beginning of wind, there is a very gradual decrease of barometrical pressure over a great extent of surface. In such circumstances, the current may commence nearly about the same time all along the line of decrement. And if, in any portion of the line, the decrement of barometrical pressure be more rapid than in others, the current will be there strongest, and first felt.

Upon this point it need only be farther remarked, that, in all cases of wind, whether arising from local aerial rarefaction or condensation, the current is propagated to windward in the one case, and to leeward in the other, with much greater rapidity than the air is itself transported.

Of the Whirlwind.—The next species of irregular wind of which we mean to treat is the whirlwind. This remarkable wind is much more limited in its extent than the hurricane, but within its sphere of action equally destructive and appalling. The diameter of the atmospheric column subjected to its influence, varies from a few feet to several hundred yards, but the whirling motion seems to be greatest at the circumference. It usually makes its appearance during summer when the sky is covered with dense clouds, and is preceded by sultry heat and a dead calmness in the atmosphere. In short, the forerunners of a whirlwind have a distant resemblance to those of a hurricane, and a very strong analogy to, if not a perfect identity with, those of a thunder or hailstorm, by which it is sometimes attended.

The following account by Abbé Richard, of a whirlwind which happened in Burgundy, in the year 1755, will give some idea of the phenomena presented, and of the effects produced by this species of tempest, when it assumes its most formidable character:—"An extremely dark cloud, hanging low in the atmosphere, and driven forward by a north wind, was observed to cover the surface of the territory in which the small town of Mirabeau is situated: it occasioned very singular appearances for about a league in length, and

the half of that space in breath. Different whirlings appeared at once in this dark mass of condensed vapours; some hail fell, and thunder was heard; the quickset hedge-rows, and most of the trees in the vineyards, were rooted up; the little river of Mirabeau was carried more than sixty paces from its bed, which remained dry; two men were enveloped in the whirlwind, and carried to a distance without experiencing any injury; a young shepherd was lifted high in the air, and thrown upon the banks of the river, yet his fall was not violent, the whirlwind having placed him on the verge where it ceased to act. In the woods within its circle its effects were traced, by finding the trees either twisted, or torn up by the roots. Some sheep that were in the fields were enveloped and carried to a distance; several of them were killed. It unroofed the farm-houses; and after raging in this manner for half an hour, the wind shifted to the south, when the tempest immediately ceased."

The cause of the whirlwind is involved in still greater obscurity than that of the hurricane. And the principal difficulty lies in explaining how such a violent, and rapid rotatory motion of the atmosphere, comes to be all of a sudden produced. One mode in which it has been accounted for is, "that the general stream of the wind, in passing over a mountainous country, is divided into a double current, each of which encountering the other at an angle, gives rise to that violent spiral or whirling motion of the air denominated whirlwind."

This explanation we consider exceedingly unsatisfactory. In the first place, it is not very apparent how

two converging currents meeting at an angle, after having been separated by a mountain, should give rise to the spiral or whirling motion. One should rather suppose that the collision of the two aerial currents, would produce merely a thorough intermixture of the atmospheric particles belonging to each of them, and thereafter, a progressive motion of the united currents, in a direction intermediate between those of the two currents before they met. In the second place, if the spiral or whirling motion was produced by the meeting of two currents at an angle after passing on different sides of a mountain, whirlwinds, instead of being very rare phenomena, as they are, would occur frequently; and would constantly make their appearance in the same locality, whenever the wind happened to be blowing in the direction, which caused the currents to meet at the requisite angle. Now, what disproves the hypothesis under consideration is, that no locality where the terrific phenomena of the whirlwind frequently present themselves, can be pointed out. Besides, waterspouts at sea, and moving pillars of sand in the arid plains of Africa, which have been supposed to depend upon similar causes with the whirlwind, make their appearance where no mountains, supposed necessary to produce converging currents, are to be found.

Others consider the whirlwind an electrical phenomenon, but they do not attempt to show how the whirling motion of the air is produced by means of electricity. Such an account of the matter, therefore, communicates no information regarding the nature, or origin of the point which is difficult to explain.

If we were to venture upon advancing any hypothesis in order to account for the nature of the whirlwind, we would ascribe it to local and sudden condensations of aqueous vapour, contained in an electrified cloud. In the case of the whirlwind above described by Abbé Richard, it was stated that "some hail fell, and thunder was heard." It is therefore presumable, that the sudden condensation of part of the aqueous vapour contained in the cloud, or possibly perhaps in detached parts of the cloud, resulted from the abstraction of the electric fluid at the time when the thunder was heard. It was also stated, that the extremely dark cloud supposed to give birth to the whirlwind, appeared hanging low in the atmosphere. The circumstance, however, of the condensed vapour descending in the frozen form of hail, indicates that the condensation of the aqueous vapour had taken place at an altitude much higher than the base of the cloud. Now, it is by no means improbable, that the various whirlings that were seen at different places of the cloud, resulted partly from local condensations of the vesicles of the cloud into hail, and partly from the condensation of the aqueous vapour in the lower part of the cloud, together with the condensation of the atmosphere underneath, in consequence of the coldness communicated during the descent of the hail. It is obvious that a sudden condensation of a portion of the atmosphere thus produced, would occasion a sudden rush of air from all directions towards the centre of the cooled and contracted atmospheric columns. Provided the centre of condensation had been stationary, the air rushing in, in all directions, would

meet in the centre, and no whirling motion would be produced. But owing to the progression of the cloud, and of the cooled atmospheric columns underneath, the air rushing in from all directions, meets in such a manner as to give rise to the whirling motion. Of course, the more sudden the condensation of the aqueous vapour and of the air underneath is, the greater will be the force with which the surrounding air will rush in to fill up the partial vacuity, and the more rapid will be the rotatory motion communicated to the converging currents. Such, in my opinion, is the most probable manner, in which the spiral movement of the atmosphere constituting the whirlwind is produced.

It may be objected to the above hypothesis, that, if it were true, whirlwinds ought to accompany every hailstorm, and even every thunderstorm. It is difficult to obviate this objection. But it is possible, notwithstanding, that the whirlwind may be occasioned as above explained. And the reason why they are not of more frequent occurrence may be, that a certain relative rapidity of progression and of condensation of vapour, and a certain degree of previous density, size, depth, and electrization of cloud, must concur, to cause the converging currents of air to meet at the determinate angle necessary to produce the rotatory motion.

Of the Waterspout or Syphon.—Similar causes to those which produce a whirlwind on land, are conceived to give rise to a waterspout at sea. It seems to depend on some spiral movement, which originates usually in a cloud of great density. When first ob-

served to assume the appearance of a waterspout, it resembles a dark cone hanging down from a very dense cloud. As the cone extends itself downwards, the sea underneath becomes very much agitated, and seems to boil and foam up towards it. At length the cone and sea underneath unite, and form one immense tube, black at the borders, and white in the middle, subjected to a rapid spiral movement, and extending sometimes half a mile in length. This immense tube, instead of remaining stationary, moves forward with the progressive velocity of the wind; and along it a great quantity of water in the form of spray, seems to be whirled aloft with a rushing noise, and discharged into the dark overhanging clouds. Towards the termination of this phenomenon, the black cloud draws itself up in a ragged form, leaving, however, a thin transparent tube, which reaches to the water where this smoky appearance still continues. If the tube separates in the middle, which not unfrequently happens, it gives way with a rushing noise, like that of a cascade descending into a deep valley; and, in a short time, the whole is dissipated in the clouds, or precipitated in heavy rain. When a waterspout appears overland, the dark cone suspended from the cloud gradually extends itself downwards, and not unfrequently, in the end, discharges itself in very heavy rain, which is found, upon examination, to be perfectly fresh, and like rain-water in general.

The force by which sea-water is carried up the tube in the form of spray, is analogous to that by which heavy bodies are uplifted by the whirlwind. When a spiral movement is communicated to a given dia-

meter of atmospheric columns, a degree of rarefaction in the interior of the moving columns, proportional to the rapidity of the motion, is produced by the centrifugal velocity. Accordingly, bodies getting within the vortex of motion, will be carried along the tube from where the centrifugal velocity is less, to where it is greater. Hence, water may either be uplifted from the sea to the cloud, or discharged from the cloud to the sea, according as the centrifugal velocity of the whirlwind increases from the sea towards the cloud, or from the cloud towards the sea. The rising or foaming up of the sea towards the cone, is the result of atmospheric pressure forcing up the water into the partial vacuity, formed by the centrifugal velocity of the whirlwind. This force of course can only be supposed to raise the water in mass to the height of a few feet. But even this degree of elevation must expose it more completely to the force of the whirlwind, by which it is dashed into spray, and in this divided form whirled aloft.

Of Pillars of Sand.—Another form in which the whirlwind manifests its power, is in raising very light sand, (such as is to be found in the arid plains of Africa,) into the form of immense pillars subjected to a whirling and progressive movement. Bruce describes a remarkable exhibition of this kind, which he witnessed in his journey to Abyssinia. The description however appears, by the more recent and more to be relied on accounts of Burckhardt, to be somewhat exaggerated. It is as follows :—" At one o'clock we alighted among some acacia trees at Waadi el Halboub, having gone twenty-one miles. We were here

at once surprised and terrified, by a sight surely one of the most magnificent in the world. In that vast expanse of desert from west to north-west of us, we saw a number of prodigious pillars of sand, at different distances, at times moving with great velocity, at others stalking on with majestic slowness. At intervals we thought they were coming in a very few minutes to overwhelm us, and small quantities of sand did actually more than once reach us; again they would retreat so as to be almost out of sight, their tops reaching to the very clouds; then the tops often separated from the bodies, and these once disjoined, dispersed in air and did not appear more; sometimes they were broken in the middle as if they were struck by large cannon-shot. At noon they began to advance upon us with considerable swiftness, the wind being very strong at north. Eleven ranged along the side of us, about the distance of three miles; the greatest diameter of the largest appeared to me at that distance, as if it would measure ten feet. They retired from us with a wind at south-east, leaving an impression upon my mind to which I can give no name, though surely one ingredient in it was fear, with a considerable deal of wonder and astonishment. It was in vain to think of flying; the swiftest horse, or fleetest sailing ship could be of no use to carry us out of this danger; and the full conviction of this rivetted me to the spot."

Of Hot Winds.—The winds usually included under this head are the sirocco, the harmattan, and the simoom. These winds have all a similar origin, and possess the same characteristic qualities.

Of the Sirocco.—This wind blows from the deserts lying to the south-west of Egypt. It is experienced along the northern shores of Africa, all over the Mediterranean sea, and even in Sicily, Italy, and Spain. In an eastern direction it is experienced in Egypt, Arabia, Persia, and even as far as Hindostan. It is characterized by extreme dryness, and great heat. The thermometer, even in Sicily, sometimes rises during its continuance, as high as 110° of Fah. in the shade. It is attended with a hazy obscurity in the air, which causes the sun to appear of a blood-red colour. This peculiarity seems to be owing to the atmosphere being impregnated with an impalpable powder, or extremely light sand, raised from the deserts, where this wind originates, and carried along with it; and which, during its continuance, is deposited on the leaves of trees, and on the surface of all other bodies exposed to it. Its effects upon the human constitution, though usually much exaggerated, seem to be to a certain extent deleterious. It in some degree obstructs respiration, accelerates insensible perspiration so much as to dry up all moisture from the skin, and produces languor, and slight dejection of spirits. As might be expected, its baneful influence is more felt in places near its source, than in those at a distance. Thus along the northern shores of Africa, its effects are stronger, than along the southern shores of Europe. Its deleterious qualities seem chiefly to depend upon its extreme dryness. Even at Malta, after having passed over two hundred miles of sea, this quality is supposed to be that which has the greatest influence in rendering it unwholesome. In

like manner at Madeira, the wind from the Great Desert in Africa, which is similar to that of the sirocco, is so exceedingly dry, even after passing over about two hundred miles of the Atlantic ocean, that the nibs of pens, in consequence of its influence in abstracting humidity from bodies, are bent in a remarkable manner during its continuance. Its injurious effects are best avoided by keeping as much within doors as possible, and by frequently sprinkling the floors with water.

Of the Harmattan.—Harmattan is the name given to a wind experienced on the coast of Guinea. As it has probably the same source, and manifests similar characteristic qualities with the sirocco above treated of, it requires no farther description.

Of the Simoom.—The Simoom, or as it is sometimes called, the Kamsen, or the poisonous blast of the desert, is the same wind as the sirocco experienced in, or near the place where it originates. Its characteristic qualities, viz., its dryness, warmth, and impregnation with dust or sandy particles, are precisely the same as those of the sirocco, only somewhat increased, in consequence of being less mitigated by distant transportation. The deleterious effects of this wind appear to be more exaggerated and misrepresented, than those of any other. For this the following reasons may be assigned :—The sandy and dusty surface of deserts exposed to the rays of a vertical sun, becomes greatly warmer, especially during the hottest period of the day, than the incumbent atmosphere. Hence, when wind suddenly springs up, particularly about mid-day, in such localities, the

clouds of heated dust thereby raised into the atmosphere, communicate to the aerial current that sudden and great augmentation of temperature, and of hygrometric dryness, which immediately and severely affects the feelings, and even the health, of men and animals exposed to it. Besides, in consequence of the great augmentation of temperature, communicated to the lower aerial strata by the rising of the heated dust, lateral currents of colder air, (which in their turn also become heated,) flow in underneath from all directions, occasioning a sort of whirlwind, whereby the dust is carried up to great altitudes in the atmosphere; and thereafter transported by means of the aerial current, before wholly descending, to great distances. These observations explain the phenomena presented by the Simoom, which, on reaching distant countries in a mitigated form, has received the names of Sirocco, and Harmattan. They also, with the assistance of the natural tendency to exaggerate whatever is remarkable, afford a tolerably rational explanation of all the exaggerated and marvellous statements, regarding the instantaneously morbific, and poisonous qualities of the Simoom.

Burckhardt gives the following apparently true and unexaggerated description of this wind:—" I never observed that the simoom blows close to the ground, as commonly supposed, but always observed the whole atmosphere appear as if in a state of combustion. The dust and sand are carried high into the air, which assumes a reddish, or bluish, or yellowish tint, according to the nature and colour of the ground from which the dust arises. The yellow, however,

always more or less predominates. In looking through a glass, of a light yellow colour, one may form a pretty correct idea of the appearance of the air, as I observed it during a stormy simoom at Esne, in Upper Egypt, in May, 1813. The simoom is not always accompanied by whirlwinds; in its less violent degree, it will blow for hours with little force, although with oppressive heat. When the whirlwind raises the dust, it then increases several degrees in heat. In the simoom at Esne, the thermometer mounted to 121° in the shade; but the air seldom remains longer than a quarter of an hour in that state, or longer than the whirlwind lasts. The most disagreeable effect of the simoom on man is, that it stops perspiration, dries up the palate, and produces great restlessness. I never saw any one lie down on his face to escape its pernicious blast, as Bruce describes himself to have done, in crossing the desert; but during the whirlwinds, the Arabs often hide their faces with their cloaks, and kneel down near their camels, to prevent the dust from hurting their eyes. Camels are always much distressed, not by the heat, but by the sand blowing into their large prominent eyes. They turn round to endeavour to screen themselves by holding down their heads: but this I never saw them do, except in case of a whirlwind, however intense the heat of the atmosphere might be. In June, 1813, going from Esne to Siout, a violent simoom overtook me upon the plain between Farshiout and Berdys. I was quite alone, mounted upon a light-footed hedjin. When the whirlwind arose, neither house nor tree was in sight; and while I was endeavouring to cover

my face with my handkerchief, the beast was made unruly by the quantity of dust blown into its eyes, and the terrible noise of the wind, and set off at a furious gallop. I lost the reins, and received a heavy fall; and not being able to see ten yards before me, I remained wrapt up in my cloak on the spot where I fell, until the wind abated, when pursuing my dromedary, I found it at a great distance, quietly standing near a low shrub, the branches of which afforded some shelter to its eyes."

Of the Characteristic Qualities of Winds.—The qualities by which winds may be characterized, are hot and dry; cold and dry; hot and moist; cold and moist; and intermediate degrees.

Winds which come under the denomination of hot and dry, are such as blow from an extent of heated land parched up by long continued drought. The sirocco, harmattan, and simoom, previously described, belong to this class. One of the characteristics of these winds, however, viz., that of being impregnated with dust and sand, is not essential to the class under consideration; but arises from the accidental circumstance of their blowing over a heated surface consisting of dust, or very light sand. Such winds are exceedingly unwholesome. They dry the palate; exhaust the body of its juices; produce languor, loss of appetite, restlessness, and dejection of spirits; and dispose the human frame to suffer from ardent fevers, and bilious disorders. Their deleterious influence is best guarded against by keeping within doors as far as convenient; by sprinkling the floors frequently with water;

and by living upon an abstemious, cooling, and moistening diet, during their continuance.

Winds which come under the denomination of cold and dry, are such as blow, during cold weather, from a cold towards a warm climate, over a great extent of land. On the continent of Europe, north and north-east winds, and in the United States of America, north and north-west winds, during the coldest period of the year, are usually of this description. North-east winds experienced in Britain during spring, though their characteristic qualities be somewhat mitigated by crossing the German ocean, belong to this class. Their piercing and refrigerating influence, is partly owing to their thermometric coldness, and partly to their dryness promoting evaporation, and thereby carrying off heat more rapidly from the human body, and all other moist surfaces. The influence of garden walls in protecting fruit trees, and other vegetable productions during cold weather, principally arises from the shelter thereby afforded against the evaporating influence of dry, undersaturated atmospheric currents.

Winds remarkable for coldness and dryness, are prolific of inflammatory diseases, such as sore throats, tooth-achs, pleurisies, and coughs and colds. Long exposure to them is peculiarly hurtful to asthmatic people, being apt to bring on what is called an asthmatic paroxysm. As exposure to such winds cannot be avoided in cold climates, their baneful influence, as well as that arising from cold in general, is best guarded against by fortifying the body, by taking sufficient exercise, and by being much in the open air.

To these means, one of the best auxiliaries is the cold bath, or if more convenient, bathing the body every morning with a sponge and cold water, upon getting out of bed. On the contrary, that which produces the greatest effect in relaxing the body, and rendering it incapable of resisting cold impressions, is, being much in warm apartments, particularly such as are heated by crowds of human beings, as theatres and concert-rooms. The injurious effects of such crowded apartments might always be obviated, by the free admission of fresh air, by allowing doors, or a small portion of the upper part of windows to remain open. What is called a draught of air which is so absurdly dreaded, in place of being hurtful, is highly beneficial even to those most exposed to it. Cold is never hurtful unless it is felt disagreeable, and is only hurtful in proportion as it is disagreeable. It is questionable if, in such heated places, any individual ever yet caught cold by exposure to a draught of air, provided the temperature of the air, notwithstanding the draught, remain in any considerable degree higher, as it usually does, than that of sitting apartments in dwelling-houses in general. Hundreds, on the other hand, have lost their lives by the corporeal relaxation induced by a heated apartment, rendering them incapable of withstanding every cold impression for several days thereafter, and which the free admission of air would have, in a great measure, obviated.

Winds which come under the denomination of hot and moist, are such as, during the warmest season of the year, are accompanied with wet weather; or such as are experienced in sultry weather on the sea coast

when the wind blows from the sea, and a warmer latitude. In all intertropical climates, the condition of the atmosphere is uniformly hot and moist, during what is called the Rainy season. In such climates, this is also the sickly season, and that in which marsh fevers prevail. It does not appear, however, that this class of febrile diseases is produced by the immediate influence of heat and moisture, for they never occur at sea, unless infection has been previously imbibed on shore. These diseases seem rather to be owing to unknown volatile substances which emanate from the soil, or from its vegetable productions, when subjected to great heat and moisture.

In order to escape marsh-fevers, persons during the sickly season in warm climates, particularly those recently arrived from colder latitudes, should live temperately, and beware of marshy, low-lying places. They should also avoid going out, either during night, or early in the morning; and their sleeping, as well as sitting apartments, should be elevated above the ground as far as convenient.

Winds which come under the denomination of cold and moist, are such as prevail during wet weather in high latitudes, or during rainy winter weather in temperate latitudes;—such, also, as on the sea-coast blow from the sea in high latitudes, even though the weather be dry.

An atmosphere unusually cold and moist, disposes the human frame to suffer from dropsy, scrofula, and other diseases that arise from relaxation, and want of elasticity in the muscular fibre. Warm clothing, nourishing and somewhat heating diet, and active exer-

cise, are in such circumstances the best guardians of health.

The general influence of the prevailing hygrometric and thermometric condition of the atmosphere upon the human constitution, may be deduced from a knowledge of the following facts. Atmospheric heat and dryness, severally and conjointly, promote perspiration, and, unless excessive, increase the elasticity and activity of the body, and enliven the faculties of the mind. On the contrary, atmospheric coldness and dampness, severally and conjointly, obstruct perspiration, and render the muscles of the body soft and deficient in elasticity, and produce a dull, phlegmatic, indolent temperament. Hence the general character of nations, with regard to the natural constitution, and temperament of body and mind, may, to a limited extent, be understood, by merely being acquainted with the prevailing hygrometric and thermometric conditions of the atmosphere, to which they are subjected; and of these a pretty accurate notion may be formed, from a geographical knowledge of the countries in which they reside.

It may also be remarked, that, owing to the powers of the human constitution, in becoming fitted to endure that to which it is accustomed, man is best adapted for living in his native climate. And atmospheric conditions, in proportion as they differ from those to which he and his forefathers have been habituated, are usually more or less injurious to his constitution. If there be any general exception to the preceding rule, it is, that emigration to a warmer, and a more uniform climate, upon the approach of old age, promotes health, and prolongs life.

In general, those climates are to natives the healthiest, and the most favourable to long life, in which the atmospheric vicissitudes, with regard to heat and dryness, are smallest and least sudden. Upon a similar principle, the nearer the condition of the atmosphere, with regard to heat and cold, and dryness and dampness, is to the mean of what we have been most accustomed, it is the more salubrious. The increased healthfulness, however, arising from such circumstances, is but very limited; for, in proportion as the body is less accustomed to thermometric and hygrometric vicissitudes in the condition of the atmosphere, so does it become less capable of bearing them. I have been told by a person who long resided in the island of Grenada, where the annual range of temperature in the shade does not exceed 5°, that the human constitution becomes so extremely sensitive to changes of temperature, that a variation, even to the extent of a single degree, is perceptibly felt by long residenters. At Plymouth, which is situated on a neck of land in the south-west of England, and very near the sea, in all directions, except the north-east, the atmosphere is usually mild, but very damp. I have been told that the native inhabitants of this place and its neighbourhood, feel the coldness and dryness of north-east winds during spring, much more severely than those who reside in the more inland counties of England.

Of the uses of winds very little need be said. As a mechanical power, atmospheric currents have been employed in propelling ships and windmills. As natural agents, they are principally instrumental in moderating the extremes of heat and cold, and in render-

ing the temperature more equal over the different parts of the earth's surface. They are likewise indispensably necessary, as the means by which the land is supplied with moisture evaporated from the ocean. If their agency, in this respect, were all at once to cease, the land would be soon converted into a barren desert, where no vegetable production could exist, and where man and all animals, for want of food, would inevitably perish.

CHAPTER IX.

ON PROGNOSTICATIONS OF THE WEATHER, WITH EXPLANATIONS OF THE PRINCIPLES ON WHICH THEY DEPEND.

The attention paid to meteorological phenomena by the mass of mankind in all ages and nations, has been principally directed to the means of foretelling the changes, and character of the weather. With this view, coincidences between certain kinds of weather, and an endless variety of phenomena presented by the celestial bodies, by clouds, and various other objects in nature, both mineral and vegetable, together with the cries and instinctive movements of animals, including birds, beasts, fishes, insects, and reptiles, have all been faithfully observed and recorded. And these, without any inquiry as to the cause, nature, and extent of the coincidences, have been severally promulgated by their authors, as infallible indicators of the forthcoming weather.

As we proceed, we will notice the more important means by which the weather may, with more or less probability, be foretold; but for the sake of brevity, will allow the mass of rubbish heaped upon this department of meteorological science, to remain unmolested.

Of Prognostications founded on past Experience.—In all intertropical climates, the returns of certain kinds of weather are periodical. In such climates therefore,

all that is necessary by way of prognostication, is to observe, and record the character of the weather that usually prevails, during the different seasons of the year. But though past experience may enable us to predict within a few days of the time of the year, when the rainy reason will commence and terminate; it does not give us such precise information, as will enable us to foretell the precise day on which such events will occur. In like manner, though past experience may enable us in hot climates, to predict the general character of the weather in any season of the year, still it does not give such precise information as will enable us to foretell that it will rain at any particular hour of a certain day, during the rainy season; though we may be able to predict with certainty, that at that season of the year, the general character of the weather will be wet.

As we recede beyond the tropics, the periodic returns of certain kinds of weather are less regular, and less to be depended upon. Notwithstanding, in all climates, there is more or less similarity in the kind of weather that occurs at certain seasons. And in certain climates, and in particular times of the year, periodic returns of the same description of weather, are more regular than in others. In all climates therefore, but especially within the tropics, and also in all inland countries in temperate and high latitudes, past experience carefully recorded and averaged for a succession of years, is the best means of foretelling the weather; and that from which the longest foreknowledge may be derived.

Of Barometrical Prognostications.—Of all the in-

struments that have been employed for predicting the weather, the barometer, or as it is sometimes called, the weatherglass, is unquestionably the best. In reality, it only intimates the atmospheric pressure, at the time and place of observation. But the variations in the atmospheric pressure have been found upon comparing coincidences, to be very much connected with the changes of weather. The following table, which was formerly inserted, gives the mean annual height of the barometer at the level of the sea, in four different places.

Places	Latitude.	Mean Barometrical Pressure.
Calcutta	22° 35′	29.776
London	51 31	29.827
Edinburgh	55 56	29.835
Melville Island	74 30	29.884

The annual range of the barometer is least within the tropics, next least within the polar regions, and greatest between the latitudes of 30° and 60°, where the annual variations of temperature, and of humidity in the atmosphere, upon which its oscillations depend, are also greatest.

The following table of the mean annual range of the barometer in a variety of places, confirms the preceding statement.

Places.		Mean annual range of the Barometer.
Quito	S. lat. 0° 13′	about 1 line.
Peru		$\frac{1}{3}$ of an inch.
Calcutta	N. lat. 22 35	$\frac{1}{2}$ an inch.
Kathmandu	lat. 27 30	.85 inch.
Capital of Japan	lat. 32 43	.85 do.

Places.		Mean annual range of the Barometer.
Paris . . .	lat. 48° 50′	$1\frac{1}{4}$ inch.
Great Britain averaged .		2 inches.
Petersburgh . .	lat. 59 56	$2\frac{1}{4}$ do.
Melville Island . .	lat. 74 30	1.86 inch.

The following are the principal rules, whereby the weather may be prognosticated with more or less probability of being correct, by means of the barometer.

1*st*, A high steady state of the barometer, indicates dry, calm, clear weather; being usually attended with great heat in summer, and hard frost in winter. On the contrary, a low and fluctuating state of the barometer, indicates cloudy, wet, and windy weather; being usually attended by coldness for the season of the year during summer, and mildness during winter.

2*d*, When the barometer rises very rapidly to a considerable height, it seldom remains long without falling. And on the contrary, when it falls much and rapidly, it seldom remains long without rising. Hence such rapid variations in height indicate very changeable weather, such as one day wet and windy, and another dry and calm. The day when the barometer sinks rapidly being usually cloudy, wet, and windy; the day when it rises rapidly, being usually clear, dry, and calm.

3*d*, The barometer usually sinks lowest, and with greatest rapidity, immediately previous to, and during the continuance of very high winds; and it continues to sink so long as the velocity of the wind is increasing; but it begins always to rise, and that generally with considerable rapidity, a short time before the wind abates.

4th, When the barometer rises very slowly and steadily, it indicates that it will continue high, and without much fluctuation, for a length of time. Hence it prognosticates a continuance of calm, dry weather.

5th, The barometer usually rises slightly when the wind changes from a warm to a cold direction; and on the contrary, sinks when it changes from a cold to a warm direction. Thus when the wind shifts from south-west to north-east during winter, it usually rises, and generally begins to do so before the change of wind actually takes place; but when it shifts from north-east to south-west during the same season of the year, it usually falls. The former of these changes commonly produces dry weather; the latter, rain.

6th, A long continuance of a high state of the barometer, is usually followed by a correspondingly long continuance of a low state, and the contrary. Hence the former of these barometrical conditions, which is usually attended with calm, dry weather, prognosticates a continuance of wet, and somewhat windy weather, so soon as the change takes place. And on the other hand, the latter of these conditions prognosticates a continuance of dry, calm weather, after the change of weather has taken place.

All the preceding rules show the great utility of a barometer at sea, in order to foretell the propriety of taking in sail, or the contrary, especially upon the approach, or during the continuance of night, when other signs of wind cannot be so well observed. Indeed so useful is this instrument for the above purposes, that no vessel ought to be allowed to sail in temperate

latitudes, where the barometrical indications are strongest, without one.

How the sinkings, and risings, and different heights of the barometer, prognosticate wet and dry weather according to the preceding rules, has been conceived to be of difficult explanation. The chief reason, however, appears to be, that windy and calm weather, and also to a certain extent the direction of the wind, upon which wet and dry weather so much depend, may be thereby with more or less certainty prognosticated.

Near the end of the third chapter we explained the reasons, (and they need not be here repeated,) why windy weather is peculiarly productive of clouds and rain ; and why a prevailing stillness in the atmosphere is favourable to dry weather, and a cloudless sky. The difficulty therefore chiefly lies in explaining, how the different heights, and fluctuations in the barometer, indicate the variations in the direction and velocity of the wind.

From comparing the range and fluctuations of the barometer in different latitudes and localities, with the annual range and vicissitudes of temperature, it is obvious, that the former are in a great measure dependent upon the latter. Thus, between the 50th and 60th parallels of latitude, where the annual range of temperature is greatest, the barometrical range is also greatest. And in localities having a great extent of land in one direction, and of sea in the other, which in general are the situations where the most sudden and frequent vicissitudes of temperature occur, the

barometer is likewise subject to the most sudden, and frequent fluctuations in height.

It may be easily conceived how great and sudden variations of temperature, produce corresponding fluctuations in the barometer. Thus, if a reduction of temperature be going on with rapidity over a large extent of the earth's surface, while, in those which are contiguous, a comparatively trifling reduction of temperature is taking place, an atmospheric current in the higher regions of the air will be generated, from where the reduction of temperature is less, to where it is greater. This will occasion an accumulation of atmosphere, and an increased barometrical pressure all over the region where the atmosphere has undergone the greatest reduction of temperature. The consequence will be, that a current in the lower half of the atmosphere will ultimately be generated, from the region of the earth where the barometrical pressure has increased, to where it has decreased. Owing, however, to the *vis inertia* of air, this latter current does not originate, till the barometrical pressure in the cold region, has become considerably greater, than what it is in those regions towards which the wind is about to blow. When the *vis inertia*, however, is overcome, and the air has begun to move in the direction from where the barometrical pressure is greater, to where it is less, it gradually acquires an increased velocity, in consequence of being subjected to a constant pressure, for a length of time, in one direction. Hence, a withdrawal of air is occasioned from the region where accumulation previously existed ; and before the acquired velocity of the aerial

current is checked by the reacting accumulation, and increased barometrical pressure of the atmosphere, the barometer sinks in consequence of the withdrawal of air, as much below the mean height, as it previously stood above it. It is obvious likewise, that the larger the extent of surface over which atmospheric accumulation and increased barometrical pressure take place, and the greater the degree in which they do take place, the subsequent withdrawal of air, and sinking of the barometer, and the reacting velocity of the atmospheric current when at its maximum, will be proportionally greater. In short, the alternate increase and decrease in the atmospheric pressure in different regions, as indicated by the alternate rising and sinking of the barometer; and the different degrees in the velocity of the wind, by which these atmospheric accumulations and depressions are reciprocally maintained between a warm and a colder climate, are analogous to the oscillations of a pendulum. The higher the pendulum is drawn from the perpendicular on the one side, the higher it subsequently rises on the other, and the more rapid is its motion through the intermediate space.

Such is an explanation of the manner in which great and rapid variations of temperature, when spread over a large extent of surface, alternately occasion proportionate risings and sinkings of the barometer, above and below its mean height; and which are accompanied with a proportionate velocity of wind in the lower half of the atmosphere, blowing alternately from a warm towards a cold, and from a cold towards a warm climate.

Simultaneous variations in the height of the barometer in different places, are also occasioned by the unequal evaporation of moisture from different parts of the earth's surface, and likewise (and in a greater degree, in consequence of its greater rapidity,) by the unequal return of that moisture to the earth in the form of rain. And these variations in the height of the barometer produce winds, the velocity of which is proportional to the difference of barometrical pressure in different places, by which they are occasioned; together with the acquired velocity, in consequence of the preponderance of barometrical pressure being for a length of time in the same direction.

When treating of irregular winds, in the eighth chapter, it was explained how the falling of rain had a local influence in diminishing the barometrical pressure, so as to produce wind. If, therefore, the precipitation of moisture to the earth's surface, in the form of rain, be proceeding with rapidity, in any part of the course of an atmospheric current, in its progress from a warm towards a cold climate, a sinking of the barometer is necessarily occasioned, and an increased velocity in the atmospheric current, towards where the rain is falling, is produced. In fact, the sinking of the barometer is frequently partly occasioned by the falling of rain, either where the sinking of the barometer occurs, or in some country not very distant. In the latter case, wind, and subsequently rain, may be occasioned, by the propagation of a similar sinking of the barometer in all directions. Supposing, therefore, the wind blowing gently from a warm towards a cold climate, such as from the south-west, during winter,

towards Great Britain, and the western shores of Europe, the falling of rain, in any part of its course, slightly sinks the barometer where it takes place. This increases the velocity of the wind, and the sinking of the barometer is thereby propagated. Hence the amount of rain in a given space is not only increased, but the boundaries of the region where rainy weather occurs is extended. This farther increases the velocity of the atmospheric current, and the sinking of the barometer, in the direction from whence the wind blows. From these observations it appears, that in any given district, the sinking of the barometer, and any augmentation thereof, may be either a concomitant of the falling of rain, from which it results, or may indicate that falling of rain has already begun in some other quarter towards which the wind is blowing; and that it may soon extend over the whole region where wind has been excited, and the sinking of the barometer propagated.

Again, the sinking or rising of the barometer indicates whether the wind blows from a warm or a cold climate. Thus it sinks when it shifts from a cold to a warm direction, and usually continues low while it blows from the latter. This has been supposed to be owing to the air from a warm direction containing a larger amount of aqueous vapour, (the specific gravity of which, compared with air, is as 5 to 8,) than the air from a cold direction. The chief reason, however, is the diminution of barometrical pressure, resulting from the general and widely extended falling of rain, which occurs when the wind blows from a warm towards a cold climate. On the other hand,

when the wind shifts from a warm to a cold direction, the barometer usually rises, and generally continues high so long as it blows from the latter. The reason of this is, that when the wind blows from a cold to a warm climate, it does so in consequence of a widely extended accumulation of atmosphere, and increased barometrical pressure, in colder regions. And as little or no rain falls when the wind blows from a cold towards a warm climate, no sinking of the barometer is thereby occasioned. And for the same reason, its progressive velocity is very seldom above ordinary; and not unfrequently so very slow, as hardly to be perceptible.

The low state of the barometer, during very high winds, has also been supposed to be partly owing to the circumstance of the atmosphere being prevented by its progressive, or if you choose, centrifugal velocity, from exerting its full perpendicular pressure upon the mercury in the basin of the barometer. And on the contrary, the greater than the usual height of the barometer, during very still weather, has been supposed to be partly owing to the perpendicular atmospheric pressure being then fully exerted.

The preceding observations enable us to understand how the direction and force of the wind, and consequently, how the weather is indicated and prognosticated by the variations in the height of the barometer. We may apply them to the explanation of the rules which we have given for prognosticating the weather by means of that instrument:—

Rule 1st. A high steady state of the barometer indicates dry, calm, clear weather, being usually attended

with great heat in summer, and hard frost in winter. On the contrary, a low and fluctuating state of the barometer indicates cloudy, wet, and windy weather; being usually attended by coldness, for the season of the year, during summer, and mildness during winter.

If a low state of the barometer, or in other words, if the atmospheric pressure, in any quarter of the world, be less than ordinary, it is obvious that atmospheric currents, in the lower half of the atmosphere, must blow thither from where the barometer stands at the mean height, or above it. Hence a low state of the barometer, if the weather be calm, prognosticates wind; and if the weather be moderately calm, indicates an increase of wind. If the direction of the wind so occasioned be from a warm towards a comparatively cold climate, the temperature of the atmosphere, and its capacity for humidity, will be gradually reduced in its progress thither. Hence the formation of clouds, and the subsequent falling of rain, agreeably to the third cause of the formation of clouds, stated in the third chapter, must ensue. On the contrary, if the barometer stands much higher than ordinary, in any quarter of the world, no aerial current, either in the upper or under half of the atmosphere, can be expected to blow thither. And as a cold atmosphere cannot, in such circumstances, be brought to rest over a warm one, nor a warm atmosphere be transported to a cold climate, which are the chief causes of the formation of clouds, few or no clouds can, in such circumstances be formed. Hence such a state of the barometer indicates dry weather. When this state of the barometer continues steady for a length of time,

it indicates that equality in the atmospheric temperature, and the causes by which it is produced, are nearly equal for a great distance around. And as wind results chiefly from great inequalities of temperature, in places within a limited distance of each other, the circumstance of the barometer being steadily high for a length of time, indicates the existence of circumstances favourable for producing dry, calm weather.

Rule 2d. When the barometer rises very rapidly to a considerable height, it seldom remains long without falling. And on the contrary, when it falls much and rapidly, it seldom remains long without rising. Hence such rapid variations in height indicate very changeable weather, such as one day wet and windy, and another dry and calm. The day, when the barometer sinks rapidly, being usually cloudy, wet, and windy; the day, when it rises rapidly, being usually clear, dry, and calm.

Upon this rule it may be remarked, that rapid fluctuations in the height of the barometer, result from changes in the atmospheric temperature going on with very different degrees of rapidity, in places within a limited distance of each other. In fact, the risings and sinkings of the barometer in such cases, usually result from the alternate accumulations, and corresponding depressions of the atmosphere in warm and in cold climates, which we formerly explained by the analogous oscillations of a pendulum. When the wind blows from the warm towards the cold district, rain usually falls, and the velocity of the wind being thereby augmented, the barometer stands low. So soon, however, as atmospheric accumulation begins to take

place in the cold district, the velocity of the wind gradually diminishes, till it entirely ceases. Subsequently reaction ensues from the cold towards the warm district. And this agreeably to what was formerly stated, when treating of the formation of clouds, is the direction which produces dryness, and consequently is usually attended only by moderate or little velocity in the atmospheric current.

Rule 3d. The barometer usually sinks lowest, and with greatest rapidity, immediately previous to, and during the continuance of very high winds; and it continues to sink so long as the velocity of the wind is increasing; but it begins always to rise, and that generally with considerable rapidity, a short time before the wind abates.

We need only remark upon this rule, that the velocity of the wind increases in proportion as the barometrical pressure in two different places is greater. Wind being dependent upon the difference of barometrical pressure in two different places, its velocity augments, and the barometer sinks, as that difference increases. The reason why the barometer in such cases begins to rise, and that generally with considerable rapidity before the wind abates, is owing to the atmospheric equilibrium being somewhat restored by the influx of air, before the acquired velocity of the atmospheric current is checked.

Rule 4th. When the barometer rises very slowly and steadily, it indicates that it will continue high, and without much fluctuation for a length of time. Hence it prognosticates a continuance of calm, dry weather.

In explanation of this rule it may be remarked, that the slow rising of the barometer indicates that the atmospheric temperature is undergoing little alteration, and is getting somewhat assimilated to a great distance around the place of observation. Such a condition of the aerial temperature produces atmospheric stillness; and atmospheric stillness, as was formerly explained, is favourable to the existence of dry weather, and a cloudless sky.

Rule 5th. The barometer usually rises when the wind changes from a warm to a cold direction; and on the contrary, sinks when it changes from a cold to a warm direction. Thus when the wind shifts from south-west to north-east during winter, it usually rises, and generally begins to do so before the change of wind actually takes place; but when it shifts from north-east to south-west during the same season of the year, it usually falls. The former of these changes commonly produces dry weather; the latter, rain.

In explanation of this rule it may be remarked, that when the wind shifts to the north-east during the winter season, it is owing to a gradual accumulation of atmosphere in colder latitudes. Accordingly, before the acquired velocity of the wind from a warm direction is checked, the atmospheric equilibrium, except for the acquired velocity, is somewhat restored; and hence the reason that the barometer usually begins to rise before the change of wind takes place; and consequently foretells that event. Farther, as a wind from a cold direction is usually not only much undersaturated with regard to humidity, and becoming gradually more so in its progress, but is also un-

favourable for those intermixtures of the aerial strata which produce clouds, a rising of the barometer when the wind is out of the south, or south-west during winter, prognosticates, not only a change in its direction, but also dry weather. And the falling of rain which attends a wind from a warm climate, such as a south-west wind in Britain during winter, is the chief reason of its greater velocity, and of the less barometrical pressure it exhibits, than a wind from the north-east, which is usually accompanied by dry weather during the same season of the year.

Rule 6th. A long continuance of a high state of the barometer, is usually followed by a correspondingly long continuance of a low state ; and the contrary. Hence, the former of these barometrical conditions, which is usually attended with calm, dry weather, prognosticates a continuance of wet, and somewhat windy weather, so soon as the change takes place. And on the other hand, the latter of these conditions prognosticates a continuance of dry, calm weather, after the change has taken place.

The causes which produce the results stated in the preceding rule, are not, and never will be, properly understood, until the simultaneous direction and force of the wind, together with the temperature and height of the barometer in a great variety of distant places, can be compared with each other, so that conclusions may be therefrom deduced. It may be remarked, however, that as a continued low state of the barometer is usually concomitant with rainy, and somewhat windy weather, the direction of the wind being for the most part from a warm climate, such a

state of the atmosphere with regard to weight, temperature, and humidity, is ultimately produced in those regions, where it has continued for a length of time to blow towards, as causes the atmospheric current to assume a contrary dry direction, for a somewhat proportional period of time. Hence the proverbial rule for prognosticating the weather: "Long fair, long foul;" and the contrary.

Of Prognostications of the Weather by means of Hygrometers.—The principle according to which the mass of hygrometers have been constructed is, that a certain degree of affinity between moisture and air, and moisture and many other substances exists. And that one substance attracts another for which it has an affinity, with proportionally less force, according as it is more nearly saturated with it. Thus, a hair, or a piece of catgut, or packthread, may be used for hygrometric purposes. Each of these substances, as well as most others, exerts a certain degree of attraction for moisture. Accordingly, as the air gets more nearly saturated, and exerts a proportionally less attractive force for humidity, those substances absorb a greater amount of moisture; and in doing so, expand in thickness, but diminish in length. On the other hand, when the air becomes drier than usual, and exerts a proportionally stronger attraction for moisture, a portion of humidity is abstracted from those bodies; and this, while it diminishes their thickness, increases their length. Hence the length of such, or similar substances, fitted up and adjusted to a scale of equal parts, according to various mechanical contrivances, has been employed as a mea-

surer of the dryness, and dampness of the atmosphere.

The different degrees of rapidity with which moisture evaporates, and reduces the temperature of the evaporating surface, according to the state of the atmosphere with regard to humidity, is another principle upon which hygrometers have been constructed. But as we do not mean to describe meteorological instruments generally, we need not farther enlarge upon this point.

Our object in making remarks upon hygrometric instruments is, that if the principles of their construction be understood, a great mass of weather indications held in esteem by the more ignorant part of the population, and which depend upon the same principles, become intelligible.

In the first and third chapters, the reasons were explained why a wind blowing from a warm towards a cold climate, though previously much undersaturated with humidity, gradually approached the point of saturation ; and it was farther explained how, by continuing in the same direction, clouds and rain were ultimately produced. It was also explained, how, when the wind shifted from a warm to a cold direction, the air soon becomes undersaturated with moisture ; and how clouds previously formed have a tendency in such circumstances to dissolve by evaporation, and dry, clear weather ensues. Hence, hygrometers, by indicating the existing dryness or dampness of the atmosphere, give information (though not always accurately,) whether the wind be in a direction favourable to the formation, or the dissolution of

clouds ; and consequently, afford a means by which wet or dry weather may, to a limited extent, be prognosticated. And supposing the hygrometer to indicate great atmospheric dryness, even though the wind should shift to a warm and rainy direction, it may take one, two, or perhaps three days, before the reduction of the temperature of the air consequent upon its transportation to a colder climate, causes it to become sufficiently damp, and before enough of moisture be precipitated into the form of clouds, to occasion rain.

The great mass of what are called signs of fair, or of wet weather, depend upon hygrometric principles. Thus, a difficulty of opening windows, window-shutters, and doors, and of drawing out wooden pegs, have been considered signs of wet weather. The reason is, wood, like all other hygrometric substances, absorbs moisture, and expands in bulk as the air becomes damper.

In like manner, the dampness, or sweating, as it is called, of certain stones, chiefly such as contain saline ingredients ; and also the unusual dampness of salt, are considered indications of wet weather ; and on the contrary, their dryness indicates dry weather. The reason is, such bodies, like hygrometric substances in general, attract more moisture from the atmosphere, according as it is nearer the point of saturation.

The peculiar cries and instinctive movements of birds, beasts, insects, and reptiles, which have been considered indications of wet and of dry weather, all result from agreeable or disagreeable sensations by which such animals are affected, when the state of the atmosphere is hygrometrically dry, or damp. In reality,

the animals themselves know nothing of the cause of the agreeable or disagreeable sensations, by which they are affected. And though they manifest those sensations by peculiar cries, and instinctive movements, they possess no foreknowledge of the weather.

In like manner, persons subject to rheumatism, and other complaints, become affected probably upon hygrometric principles, with their constitutional diseases, when the atmosphere becomes damp ; and feel relieved upon the return of dry weather. Such persons may be considered living hygrometers.

Indeed, when it is considered, that perspiration is more or less obstructed by increased dampness, and that the feathers of birds, and the hair covering the skin of beasts, as well as the muscular fibres of animals in general, are all better or worse hygrometers ; it is no wonder that variations in the dryness or dampness of the atmosphere, should give rise to agreeable or disagreeable sensations. Nevertheless, as properly constructed hygrometric instruments, afford comparatively, much more accurate means of ascertaining the different degrees of atmospheric dryness and dampness ; and as all the subsequently mentioned indications of wet or dry weather, are merely less perfect, and less precise methods of giving us similar information, they need be no longer regarded as weather prognosticators.

It may be remarked, however, that as hygrometers only give information regarding the dryness and dampness of the lower atmospheric strata by which they are immediately surrounded, and which are affected by all the vicissitudes of temperature which occur during

the alternations of day and night, they must be regarded, even when constructed upon the most improved principles, as very imperfect instruments for prognosticating the weather, which chiefly depends upon changes going on in the elevated regions of the atmosphere. They are also subject to another defect. Like all other solid bodies, they absorb radiating caloric, and accordingly, grow warm more rapidly than the atmosphere, when temperature is on the increase; and on the other hand, radiate caloric, and grow cold more rapidly than the atmosphere, when temperature is on the decrease. In the former case, they over-indicate the dryness of the atmosphere; in the latter, they over-indicate its dampness. On these accounts it has been frequently observed, that hygrometers have indicated a considerable degree of dryness, particularly during day and summer, when rain of long continuance was about to commence. And on the other hand, they have frequently indicated a great degree of dampness, and accordingly, have erroneously prognosticated wet weather, particularly upon the approach, and during the continuance of night, when atmospheric stillness, a cloudless sky, and a high settled state of the barometer, gave us every assurance of the continuance of dry weather.

Of the Prognostications of the Weather by the appearances of clouds.—1. When clouds are observed to break up into fragments, and gradually to dissolve by evaporation, it indicates that the region of the atmosphere in which they float is undersaturated with moisture, and prognosticates dry weather. On the contrary, after a continuance of dry weather, when

clouds are observed to form; or when previously formed, are observed to increase in bulk and density; and also when small detached clouds unite together and form larger clouds, it indicates that the causes immediately instrumental in the formation of clouds are in operation, and prognosticates that wet weather will soon follow. Indeed, the hygrometric condition of the elevated regions of the atmosphere in which clouds are formed, and whether causes favourable to their formation or dissolution, and consequently, whether causes favourable to subsequent wet or dry weather, are then in operation, may with great certainty be prognosticated, by observing whether, and with what rapidity, previously formed clouds, particularly those of the fleecy kind, dissolve by evaporation, or increase in bulk by farther precipitation of humidity.

2. When the whole sky is covered with clouds, their farther formation and increase in bulk and density, is indicated by their descent to a lower level, and their decrease, by their ascent. Accordingly, when clouds begin to sit down on the tops of hills, (except when this is the result of reduction of temperature, upon the approach of night,) it prognosticates rain; and when they begin to rise above the hills, it prognosticates dry weather.

3. Mist extending upwards from the surface of the earth on a summer morning, foretells a dry warm day. The peasantry give such a mist the name of heat, meaning thereby that it foretells a warm day. Such morning mists result from coldness, induced upon the earth's surface by the radiation of caloric during night, being propagated upwards to the atmosphere in suffi-

cient intensity to produce atmospheric oversaturation, and the precipitation of moisture into the forms of dew and mist. This only happens, as was formerly explained, when treating of the formation of the stratus, during calm, starry, cloudless nights, which are the usual concomitants, and among the most certain prognosticators of dry settled weather.

4. During frosty weather, the dissolution of mist, and the appearance of small detached roundish clouds of the cirro-cumulus kind in elevated regions of the atmosphere, and partly or wholly obscuring the sky, foretell that the termination of the frost is at hand. The reason is, that a sufficient degree of cold to produce frost on the surface of the earth in this climate, even during the depth of winter, can only be maintained by the free radiation of caloric from the earth's surface. Whenever, therefore, the radiation of caloric from the earth's surface is interrupted or retarded by a canopy of clouds, the heat slowly passing by conduction from underneath, upwards, and not, or only very slowly, escaping by radiation, soon accumulates in sufficient amount at the earth's surface, to cause the frost to disappear.

Of Prognostications of the Weather from the colour of the sky, and the appearances of the heavenly bodies.—The darker the colour of the sky is when viewed perpendicularly upwards, the more it indicates dry weather; and on the contrary, the paler it is, the more favourable to wet weather. It was formerly stated that the gaseous elements of the atmosphere were altogether invisible; and that the sky would appear jet black, that is, would reflect no light what-

ever, were it not for the aqueous vapour which the air contained. The circumstance of the sky presenting any colour therefore but jet black, is owing to the reflection of light, (which is itself of a white colour,) by aqueous vapour. And the reason assigned for the blue shade is, that the blue rays are reflected more copiously than any of the others. Now, as the deviation of the colour of the sky from jet black to blue white, is produced by the power of aqueous vapour in reflecting light; it is obvious that the stronger the light, or the larger the amount of aqueous vapour contained in the atmosphere by which light is reflected, the paler the colour of the sky ought to be. And on the contrary, the less light, and the smaller the amount of aqueous vapour contained in the air, the nearer should the blue shade approach to black. In forming an opinion of the future weather from the colour of the sky, it is to be recollected, that the points of observation compared at different times, must be equally distant from the zenith, and from the direction of the sun. The reason why these circumstances require to be attended to is, that the colour of the sky becomes paler in proportion as the amount of light is greater, or the point of observation nearer the direction of the sun, or nearer the horizon. Supposing the amount of aqueous vapour contained in the air, and the amount of light to be the same, most light is reflected by the aqueous vapour which is nearest the direction of the sun, and accordingly, the colour of the sky becomes darker, the farther the point observed recedes from the direction of that luminary. And other things equal, the colour of the sky appears

darker according as it is viewed more perpendicularly upwards, because the amount of aqueous vapour contained in the line of view which reflects the light, increases from the zenith to the horizon.

When the colour of the sun or moon appears pale and dull, it indicates wet weather; and on the contrary, when it is bright and clear, it indicates dry weather. The nature of this prognostication is also obvious. Though aqueous vapours reflect light, they have a proportional influence in intercepting the direct luminous rays of the sun and moon. Hence, when the sun and moon look paler and duller than usual, or in other words, give less light, it indicates that the amount of aqueous vapour contained in the intermediate atmosphere, relative to its capacity, is greater than usual; and that a larger proportion of the light transmitted by the sun and moon, is thereby intercepted. On the other hand, when the sun and moon look brighter than usual, it indicates, that there is an unusually small amount of aqueous vapour contained in the intermediate atmosphere relative to its capacity; and accordingly, an unusually small proportion of the sun and moon's light is thereby intercepted.

For similar reasons, when the horns of the moon are sharp, or when the margin of the moon generally is well defined, it indicates dry weather; and on the contrary, when the horns of the moon are blunt, and its margin somewhat ill-defined, it foretells wet weather. The nature of this prognostication is analogous to the one preceding. When the amount of aqueous vapour in the air is larger than usual, the

aqueous vapour contained in the atmosphere, in the direction between the spectator, and the sky in apparent contact with the margin of the moon, reflects the moon's light with so much intensity, that it can hardly be distinguished from the direct rays of the moon, rendered less vivid in consequence of a portion of them being intercepted by aqueous vapour. Hence, in such circumstances, the horns of the moon appear blunt, and its margin somewhat imperfectly defined. On the contrary, when the amount of aqueous vapour contained in the atmosphere is much smaller than usual, a small portion of its direct rays is intercepted, and less of its light is reflected by the aqueous vapour contained in the atmosphere apparently immediately exterior to the margin of the moon, as seen by the spectator at the surface of the earth. In such circumstances, the moon itself looks unusually clear and bright, while the colour of the sky by which it is surrounded, is unusually dark. Hence, owing to the contrast of its own brightness, and the unusually dark coloured sky by which it is surrounded, its horns appear sharp and vivid, and its margin generally well defined.

In like manner, when the moon is surrounded by an iris, it indicates rain. The reason of this is, that the iris is produced by the moon's light being reflected by aqueous vapour contained in the atmosphere, between the spectator and the sky apparently exterior to the margin of the moon. The iris therefore indicates an unusual quantity of moisture in the atmosphere, and hence the reason that it indicates rain.

Supposing no moon visible, if the stars look larger

and somewhat paler, less vivid, and at the same time less numerous than usual, it indicates an unusual amount of moisture in the atmosphere, and accordingly foretells rain. On the contrary, when the stars look smaller, more twinkling, and at the same time more numerous than usual, it indicates an unusual smallness in the amount of aqueous vapour in the atmosphere, and accordingly foretells dry weather. The increased apparent size of the stars results from the reflection of their light by aqueous vapour, contained in the atmosphere immediately exterior to their apparent margin. The diminution in their numbers results from many of them becoming invisible, in consequence of a larger proportion of their direct rays being intercepted, by the more than ordinary amount of aqueous vapour contained in the atmosphere.

In reality, all the preceding prognostications of wet or dry weather deduced from the colour of the sky, and the appearances of the heavenly bodies, indicate merely that more than the ordinary amount of aqueous vapour is contained in the atmosphere in the one case; and less than the ordinary amount in the other. The reason why a greater than the ordinary amount of aqueous vapour in the atmosphere foretells wet weather, is, that in such circumstances, its amount is usually upon the increase. And this may be owing to the wind being in a rainy direction. On the contrary, the reason why a less than the ordinary amount of aqueous vapour in the atmosphere foretells dry weather, is, that the wind, in such circumstances, is usually out of a dry quarter, and generally little of it. Besides, clouds and rain are sooner produced by a

favourable combination of the ordinary causes, when the air is saturated, or nearly saturated with aqueous vapour, than when it is much undersaturated. Upon the whole, weather prognostications deduced from the colour of the sky, and the appearances of the heavenly bodies, are fully as much to be depended on, as those deduced from the indications of hygrometric instruments. The former, though they give less precise information, are free from several sources of error, such as vicissitudes of temperature near the earth's surface, and the circumstance of temperature being upon the increase, or decrease, to which the latter are exposed.

Of Prognostications of the Weather from the Direction and Force of the Wind.—If we could predict how long the wind was to continue in the direction in which it happens to be, and without altering its velocity; and if we could also predict when, and to what extent, its direction and velocity would alter, prognostications of the weather deduced from the direction and velocity of the wind, would be more to be relied on, than any, or even all of those before-mentioned. Indeed, the claims which the before-mentioned prognostications of the weather have to correctness, or rather to the probability of being correct, (for weather prognostications in this insular climate have no higher pretensions than probability,) depend chiefly on their indicating imperfectly, whether the wind be blowing from a wet or a dry direction; and whether it be blowing with greater, or less velocity. But though it cannot be predicted how long the direction and velocity of the wind may continue without

changing, still, by prognosticating upon the supposition, that the direction and velocity of the wind will continue as it is, there is more or less probability, at least for one, two, or perhaps three days thereafter, that our anticipations will be correct. Thus, if the wind, during the winter season, be blowing with considerable, or at times, with great violence from the south-west, (that is, from a warm and wet direction,) especially if it has been shortly previous for a considerable length of time out of the east, or north-east, it may be predicted, if wet weather has not already commenced, that it will very soon begin ; and that it will last one, two, or three days, or perhaps longer,—the probability of the prediction being correct, diminishing in proportion as the anticipation of the direction and velocity of the wind and weather continuing as it is, extends prospectively to a greater length of time. On the other hand, if the wind, during the same season of the year, blow from any point between north and east inclusive, (that is, from a cold and dry direction,) and with very little velocity, it may be predicted, that the weather will continue dry and frosty, or inclined to frost, for one, and with diminishing probability of being correct, for two, three, or more days thereafter.

At Glasgow, I have almost never seen it rain when the wind was within three points of the compass, either to the east or west of north. But a wind from these points is, in this country, exceedingly rare. I have frequently seen rain when the wind blew out of any other point of the compass. At Glasgow, rain is of much more frequent occurrence, when the wind is out

of some point of the compass between south-east and west inclusive, than when the wind is out of any cold point of the compass to the north of west or of south-east.

In general, the greater the velocity of the wind, and more especially if it be out of a warm direction, the greater is the probability of rain. And on the contrary, the less the velocity of the wind, be its direction what it may, but especially if it be out of a cold direction, the less the probability of rain.

After the lengthened explanations given in the third chapter, of the influence of certain directions of the wind in forming clouds, and producing rain; and of certain other directions, in dissolving clouds and producing fair weather, (and to which we refer,) it is unnecessary farther to enlarge upon this department of our subject. It may be remarked, however, that when the wind is out of a cold and dry direction, and very little of it, and all the other means of prognostication indicate a continuance of dry weather; a change of the wind to a warm and wet direction, and an increase in its velocity, very soon reverses the prognostications to the indication of wet weather.

In all anticipations of the character of the weather, it is advisable to draw our conclusions from a variety of the means of prognostication. Thus not only the present and immediately previous condition of the barometer should be taken into account, but also the direction and force of the wind, and the appearances of the clouds and sky. The propriety of this recommendation is evident from considering, that the different means of prognostication give sometimes the

same, and sometimes opposite, indications. If, for instance, the barometer is high, and has been gradually rising for several days previous, while the wind is from a rainy direction, such as from the south-west in this island, the probability of such a wind bringing rain is much less than if the barometer was low, and had been gradually sinking for several days previous. In like manner, a cloudless, or nearly cloudless sky, is a less certain indication of dry weather continuing, when a wind of considerable velocity blows from a rainy southerly direction, than when there is very little wind, and its direction is from the north of due east, or due west.

Of Prognostications of the Weather from the Moon's age.—It has been very generally supposed that at the change of the moon, or at some other fixed period of the moon's age, the weather has a tendency to undergo an alteration. This popular belief appears to have no solid foundation in truth. It seems to have originated, and to have been perpetuated, principally in consequence of the moon being known to be the chief agent in the production of tides in the ocean; and partly, perhaps, to the word change being applied not only to the weather, but to that period of the moon's revolution when it comes most directly between the earth and the sun. Thus a change of moon, and a change of weather, are phrases in equally common use.

Changes of weather may be from cold to warm, from dry to wet, from calm to windy, or the contrary of these. But no good reason can be assigned why the moon should have more influence in producing

any of those changes of weather at one period of her age, than at another.

It has never been ascertained that heat is communicated to the earth by the moon's rays. Consequently, it can never be admitted that the moon has any influence in changing the weather from cold to warm, and from warm to cold; nor in regulating in any way the temperature on the earth's surface. In fact, nothing is more certain, than that the variations of temperature throughout the year, depend upon the alternate progress of the sun to the north and south of the equator, and not upon that of the moon.

Again, in all climates to the north and south of the torrid zone, changes of weather from dry to wet, and from wet to dry, depend chiefly upon certain alterations in the direction of the wind; and the alterations in the direction of the wind which produce those changes, are different in different countries. When treating of winds, it was shown that their existence, and variations in direction and velocity, principally depend upon variations of temperature; and upon the different amounts of moisture evaporated, and condensed into rain, in different places; and these also chiefly depend upon variations of temperature. Indeed, I have never seen it even hinted in the writings of any meteorologist, that the moon had any influence whatever, either in producing wind, or in regulating its direction and velocity. Now, as the direction and velocity of winds principally depend upon variations of temperature, and as variations of temperature depend upon the sun, and not upon the moon, it can never be admitted that the moon has any influence in

changing the weather, either from wet to dry, or from dry to wet.

Again, though the change of moon happens at the same time all over the earth, it is well known that changes of weather are by no means simultaneous in places not very distant from each other. And farther, the changes of weather which occur even in countries similarly situated with regard to the direction of land and sea, and not very distant, are not unfrequently the reverse of each other. Now, reasoning according to analogy, the same cause, in similar circumstances, is always expected to produce the same result. But to ascribe wet weather at one time, and dry weather at another, and more especially opposite kinds of weather simultaneously existing in countries similarly circumstanced, and not very distant from each other, to the change of the moon, or to any other period of her age, is attributing opposite effects to the same cause.

It may be farther remarked, that after comparing, by means of a meteorological journal, the times when changes of weather occurred, with the changes of the moon, and with other periods of her age, I am satisfied, that there is no connection between them. It is usual for those who believe in the moon's influence, to ascribe to the change of moon all alterations of the weather which happen within two or three days thereafter. In this insular climate, where the weather is so exceedingly variable, it is not surprising, that with so much latitude in point of time, innumerable coincidences should have been observed. It may be safely asserted, however, that with a similar latitude, not only

the time when the moon changes, but any other period of her age, might be at random fixed upon, and equally satisfactory evidence of her influence in producing a change of weather would be obtained.

Of the Prognostications of the Rainbow.—When the sun, relative to a spectator on the earth's surface, is in an opposite direction of the heavens from a cloud from which rain is falling, what is called a rainbow is seen. It consists of two bows or arches of light, stretching across the sky, and decomposed into their elementary colours by refraction. The internal, or principal rainbow, which is often seen without the other, has the violet rays innermost, and the red rays outermost; and forms a segment of a circle, whose diameter is 82°. The external, or fainter rainbow, has the violet colour outermost, and the red innermost; and forms part of a circle, whose diameter is about 104°.

The rainbow is produced by the reflection of a portion of the solar light, from the interior of the numerous drops of falling rain, to the spectator, after being refracted into its elementary colours, according to their different degrees of refrangibility, both in entering and in emerging from the drops. And as the rain-drops are spherical, the portion of light returned to the spectator in the refracted state, from different portions of the falling rain, previously undergoes the same angular refractions and reflection. Consequently, the angle formed by the sun, the spectator, and each colour in every part of the rainbow, is the same. And hence the reason that this phenomenon presents itself in the form of a segment of a circle.

When the sun's rays cease, in consequence of the intervention of cloud, to strike upon any portion of the falling rain, where the rainbow is seen; or whenever rain ceases to fall from any portion of the cloud, that portion of the rainbow ceases to be visible. And upon a similar principle, when clouds from which rain is falling wholly obscure the sky, and accordingly, when the solar rays strike upon the upper surface of the clouds, no rainbow is visible to a spectator on the surface of the earth.

Clouds, so long as they consist of aqueous vapour in the vesicular form, never produce a rainbow. It is only moisture that has lost the vesicular constitution, and which is descending to the earth in the form of rain, which produces this phenomenon. The fact of spray which rises from a waterfall exhibiting, during sunshine, the refracted colours of the rainbow, proves that its constitution is analogous to that of falling rain, and different from the ordinary vesicular constitution of clouds.

The prognostication of the rainbow extends no farther than giving intimation, that rain is falling from the cloud where the rainbow is visible. If the direction of the wind be such, as to cause the cloud to pass over the place where the observer of the rainbow is situated, rain may there be expected soon to fall. But if the direction of the wind be such as to cause the cloud to pass, without becoming vertical to the spectator, no rain in the situation where he is need be expected.

Of the Prognostications of a cold, and also of a mild winter.—The principal prognostication of a cold

winter, is unusual coldness during the preceding summer; and this is always with greatest accuracy ascertained by the unusual lateness of the harvest. A cold summer is on all occasions a cloudy and wet one. The reason why a cold, cloudy, wet summer, foretells that a cold winter will probably follow, is that an unusually large proportion of the solar heat, which ought to be imbibed by the earth during summer, is partly intercepted by clouds before reaching the earth, and partly carried off from its surface by evaporation. During winter, the temperature of the atmosphere is principally supported by the retrocession of solar heat, absorbed by the earth during the previous summer. But if owing to the above-mentioned causes, the amount of solar heat absorbed by the earth during summer, be smaller than usual; the amount returned to the atmosphere from the earth during winter, will also be smaller. Hence, if other circumstances be in an ordinary degree favourable to coldness, the reduction of the atmospheric temperature during winter will be greater than usual.

Another prognostication of a cold winter, and which, if it co-operates with the preceding prognostication, increases its effect, is much rain in the fall of the year, (namely, in August, September, and October,) followed by an unusual prevalence of northerly and easterly winds, during October and November. These dry winds, by increasing evaporation from a thoroughly moistened soil, prematurely carry off a larger proportion than usual of that heat, which, by its slow retrocession from the earth's surface, ought to mitigate the atmospheric coldness during the depth of winter.

Hence, if other circumstances be in an ordinary degree favourable to coldness during the coldest period of winter, the atmospheric temperature should then sink lower than usual.

The two preceding prognostications, viz. a cold wet summer, and heavy rains in the fall of the year, followed by an unusual prevalence of northerly and easterly winds, occurred during the summer and fall of 1708, and was succeeded in the end of that year, and in the beginning of 1709, by one of the severest winters on record.

Having observed that the two preceding prognostications of a cold winter, had occurred in the year 1830 to a greater extent than usual, I ventured to predict in the Glasgow Chronicle Newspaper, (and it was the only time I ever did so,) before any cold weather commenced, that the winter would be colder than ordinary. The prediction was to a certain extent verified. The winter was colder than any that has happened since, or than any that had occurred for at least ten years previous. There was skating on the Clyde at Glasgow that winter, on two separate occasions, for about ten days each time; and there was subsequently an unusual fall of snow. It was, however, a mild winter, when compared with the remarkably severe one of 1814.

A mild winter may be prognosticated by the occurrence of the opposite circumstances to those previously stated, which foretell a cold winter. The first of these is a warm, dry summer, which can always be best ascertained by the unusually early period at which harvest in such years commences. The other prognos-

tication is a small, or only a moderate amount of rain in the fall of the year, attended and followed by an unusual prevalence of south and south-west winds, of very little, or only moderate velocity.

In our insular climate, the fulfilment of the prognostications of a cold winter, may be prevented by the unusual prevalence of south, and south-west winds, (and the stronger, the more efficacious they are,) and also by the unusual prevalence of clouds and wet weather, and even by dense fogs, during what should be the coldest period of the year. In like manner, the previous prognostications of a mild winter may be rendered somewhat inaccurate, by the unusual prevalence of northerly and easterly winds of very little velocity, and also by an unusual clearness of the sky, and freedom from clouds, and dense fogs, during what should be the coldest period of winter.

It has been remarked, that an unusual crop of what are called *heps* and *haws*, prognosticates a severe winter. As an abundant crop of these vegetable productions results from, and indicates an excess of moisture, and unusual coldness during the previous summer, which may always be ascertained with more precision by the lateness of the harvest, this prognostication requires no farther explanation, and may be altogether neglected.

Another prognostication of a cold winter is, the arrival in the fall of the year, at an earlier period than usual, of migratory birds, such as woodcocks, which spend the summer in the northern parts of Europe, and winter in this island. The early appearance of such birds is supposed to indicate, that cold

weather in the northern parts of the continent of Europe has commenced sooner, and with greater severity, than ordinary; and that it will, in course of time, extend to this country. I have repeatedly observed prognostications of a cold winter, founded upon the early appearance of migratory birds, announced in newspapers. But whether it was owing to an error in the announcement, or to some other cause, I have never seen one of those predictions turn out correct.

In like manner, warm summers are predicted when migratory birds, such as swallows, from Africa or the south of Europe, arrive earlier in this country than usual. Their early appearance is supposed to indicate, that warm weather in southern climates has commenced sooner than usual, and that it will by and bye extend to this country.

During calm clear weather, the minimum temperature of night may be prognosticated, by ascertaining the hygrometric state of the atmosphere. The temperature, or perhaps one degree lower than the temperature at which the atmosphere becomes saturated with moisture, and precipitation of humidity in the form of mist commences, is the limit to its reduction during night. The principle upon which this prognostication depends is, that the heat evolved during the conversion of invisible vapour into mist and dew, prevents the atmospheric temperature from being farther reduced.

Of Cycle Prognostications.—It has been a common belief in different ages and nations, that after a limited number of years, the same succession of weather in the different seasons of the year recurs, and

is repeated periodically. It does not appear, however, that there is any satisfactory evidence founded on authentic and precise observations of the weather, that such is the case. Indeed, the circumstance of the duration of the cycle being considered different by different individuals, is a proof, that if it exists at all, its duration has never been accurately ascertained. Nine years, or some multiple of nine years, has been generally fixed upon as the period of the cycle. Thus nine, eighteen, thirty-six, and fifty-four years, have been all severally fixed upon by different individuals.

According to Toaldo, the cycle consists of nineteen years; and upon this supposition, a table of the weather for several centuries has been made out. The following portion of the table applicable to the past and future years of the present period, and which may be extended for any length of time, we subjoin by way of example :—

				Character of the Seasons.
1795	. 1814	. 1833	. 1852	Warm and dry.
1796	. 1815	. 1834	. 1853	Variable, moist.
1797	. 1816	. 1835	. 1854	Variable.
1798	. 1817	. 1836	. 1855	Warm and dry.
1799	. 1818	. 1837	. 1856	Do.
1800	. 1819	. 1838	. 1857	Do.
1801	. 1820	. 1839	. 1858	Cold and moist.
1802	. 1821	. 1840	. 1859	Mild and dry.
1803	. 1822	. 1841	. 1860	Ordinary.
1804	. 1823	. 1842	. 1861	Cold and moist.
1805	. 1824	. 1843	. 1862	Cold, tolerably dry.
1806	. 1825	. 1844	. 1863	Ordinary, cold and moist.
1807	. 1826	. 1845	. 1864	Cold and moist.
1808	. 1827	. 1846	. 1865	Rather cold and moist.
1809	. 1828	. 1847	. 1866	Ordinary.

				Character of the Seasons.
1810 .	1829 .	1848 .	1867	Ordinary.
1811 .	1830 .	1849 .	1868	Cold and dry.
1812 .	1831 .	1850 .	1869	Variable, moist.
1813 .	1832 .	1851 .	1870	Warm, dry.

It is difficult to compare the weather for a whole year, with the very brief description given of it in the preceding table. The only way of ascertaining whether the duration assigned to cycles be correct or not, is to note those years, when the weather, during particular seasons, is very uncommon. Thus, the beginning of the year 1795 was remarkable in Scotland, for a greater snow-fall than had occurred for many years previous; and greater than any thing of the kind that has taken place since. The snow-fall commenced that year on the 2d day of February, and, owing to the continuance of frost and cold weather, was not wholly melted for a long time thereafter. Nineteen years subsequently, a more severe frost (not however accompanied with snow,) occurred, than had been seen for an unknown length of time previous, and infinitely more severe than any thing that has taken place since. By Christmas, 1813, there was skating on the Clyde at Glasgow, and the ice continued unbroken till near the end of March, 1814. Large masses of ice left on the banks of the river, after the ice broke up during a flood, measured eighteen inches in thickness. And this, in consequence of several days' thaw before the ice broke up, must have been considerably less than what it had previously been. The thermometer which I was in the habit of examining at that time, did not indicate any

temperature lower than 7° above zero of Fahrenheit, —this probably being regarded by the maker of the instrument, as being as low an indication of temperature as was ever required in this climate. During this remarkable winter, however, every night between 9 and 10 o'clock, P.M., for a considerable length of time, the mercury in the thermometer was sunk into the bulb, which indicated that the temperature was under 7° above zero of Fahrenheit. And one morning, about an hour before sunrise, it was stated in the Chronicle newspaper, that, at their office, near the centre of the city, the thermometer stood at the remarkably low temperature of 14° below zero. Nor was the severity of the cold restricted that winter to Great Britain. I have been told by a gentleman who was then residing in Sweden, that the frost was there incomparably more severe that winter, than it had been for at least sixty years previous.

If it be thought that the circumstance of the severe frost in the beginning of 1814 being nineteen years after the frost, and heavy fall of snow, in the beginning of 1795, corroborates Toaldo's notion, that the cycle consists of nineteen years; the fact of the winter of 1833, viz., nineteen years after 1814, being so mild, that the Clyde at Glasgow never froze at all, disproves his hypothesis.

We may state other years that have been remarkable, in order to afford points of future comparison, with a view to ascertain whether cycles exist or not. The winter of 1833-4, viz., November and December of 1833, and January of 1834, was the wettest and windiest winter recollected to have ever happen-

ed by the oldest person in Great Britain. That winter was also remarkable for a mild temperature, and for the almost total absence of frost, fog, and snow. The summer of 1826 in Scotland, was the driest and warmest, and produced the earliest harvest, that has occurred since that time, or that had occurred for a considerable period previous.

The cycle of eighteen years duration, is proved to be untrue by the fact, that the winter beginning with January 1832, viz., eighteen years after the great frost, was so mild, that the ice upon the Clyde at Glasgow, was never sufficiently thick for skating upon. The cycle of nine years is also disproved by the winter of 1822-3 being exceedingly mild, when compared with the severe winter which occurred nine years previous. The cycle of thirty-six years is somewhat supported by the fact, that an unusually heavy fall of snow occurred in Scotland in the beginning of February 1831, just thirty-six years after the more remarkable snow-fall which commenced on the 2d of February 1795. There was this difference, however, between the two: the snow-fall in 1795 continued on the ground for a very long period thereafter; whereas, that which happened in 1831, being succeeded by a rapid thaw accompanied with rain, which produced great river inundations, had entirely disappeared within about a week of the time it fell.

The cycle of fifty-four years has been recently advanced by one George Mackenzie, who of late years has annually issued a small quack-looking publication, entitled, a Manual of the Weather; in which he pretends to foretell the character of the weather

for every month of the succeeding year. I have only examined the Manual which commences with November, 1833, that being the period when his year of the weather begins. Upon comparing his predictions with a meteorological Journal which I have kept, I find, that whenever his prognostications are distinctly marked, so as to admit of comparison with what actually occurred; or when the weather happened in any month to be very unusual, which frequently occurred in that year, he has had the misfortune to be oftener wrong than right. To enumerate all his errors in prediction, small as well as great, is unnecessary. We will only notice the following by way of sample :—Under the head of rain for the month of December, 1833, he says, "Days rain, average; slight rains, under average; mean rains, above average,—hence the average quantity of rain: consequently this ought to be a fine month, notwithstanding of some excess of strong wind; and the more welcome on account of its position,—mid month of the winter quarter,—but the summer will more than balance this rather unseasonable weather."

Instead of the amount of rain being only average, and of its being a fine month, with only some excess of strong wind, as the prediction tells us, it was one of the stormiest and cloudiest months on record; and the amount of rain that fell, was said to be greater than had fallen in any month for at least thirty years previous. By the register kept at the Macfarlane Observatory, Glasgow, by Dr Couper, the total amount of rain that fell in the year 1833 was 19.908 inches; and of that quantity no less than 5.202 inches fell in

December. By the register kept at Anderson's University, Glasgow, the total amount for the same year was 26.32 inches; and of that quantity no less than 6.63 inches fell in December, being, by both registers, more than a fourth of the whole that fell during the year; and as much as fell during any other three consecutive months throughout the year.

In the month of April, 1834, he predicts an excess of rain, whereas it turned out to be one of the driest Aprils ever recollected. Again, he predicts during the summer months of 1834, viz. May, June, and July, an excess of cloudy, wet, and cold weather; and that the harvest must be a late one. Instead of this being the case, the summer of 1834 was warmer, drier, and the sky in general considerably clearer than usual; and the harvest all over Great Britain, was earlier than it had been any year since the remarkably dry summer of 1826.

He also predicts that the amount of foggy days throughout the year, would be considerably over average; and that the sum total of frost would be a full average, or inclined to over-average. Now, mark what actually took place. Owing to the high winds which prevailed throughout the winter, and which is the only season when fogs occur in this island, there was a remarkable deficiency of foggy weather. And as to frost, I never witnessed a year in which there was so little. To say more regarding Mackenzie's Manual, would be taking more notice of it than the trash it contains deserves.

The three most severe frosts recorded to have happened in this country, and in Europe generally, dur-

ing the last or present century, occurred in the beginning of the years 1709, 1783, and 1814. The intervals between these several years of great frost, are at variance with any of the periods assigned for the duration of cycles.

According to Humboldt, the years in which the greatest amount of rain fell in Mexico, are as follow: 1553, 1580, 1604, 1607, 1629, 1648, 1675, 1707, 1732, 1748, 1772, 1795. The intervals between the above years, besides being irregular, are also at variance with any of the periods assigned for the duration of the cycle.

The principle upon which the cycle of eighteen years is said to be founded, is, that every eighteen years, or a little more than eighteen years, the sun, the moon, and the moon's node, come to the same relative positions. The facts, however, which we have above stated, show that that circumstance has no perceptible influence in producing a recurrence of the same kind of weather.

In a book entitled "A Rational Account of the Weather," published in the year 1738, by John Pointer, M.A., Rector of Slapton, in the county of Northampton, and diocese of Peterborough, a series of wet seasons, which seem to have occurred about that period, are ascribed to the excessive use of gunpowder in war. In this misnamed publication, many equally philosophical explanations of meteorological phenomena may be found. Not only rain, but the Aurora Borealis, thunder and lightning, and other phenomena, are considered results of the explosions of gunpowder.

Supposing that the aggregate amount of heat communicated to the earth, and of moisture evaporated from the surface of the land and water, to be the same in each year, it is obvious, that the aggregate amount of moisture annually returned to the earth in the various forms of rain, snow, hail, and dew, must also be equal. Hence, wet and dry seasons, which, according as they happen in summer or in winter, produce unusual coldness, or unusual warmth for the time of the year, may be regarded as mere local peculiarities, occasioned principally by differences in the direction and force of the wind, during the corresponding seasons of different years. Thus, winds which produce wet weather in one climate, are found to occasion dry weather in another. And if different kinds of weather, simultaneously occurring in different countries, and climates, could be adjusted against each other, according as they deviate from the mean, it is not unlikely, but that the annual aggregate of weather prevailing over the earth's surface, would turn out to be always the same, or very nearly so. Upon similar principles, it is not improbable, that, by means of some compensating causes, not yet understood, each climate, within a limited, and perhaps somewhat irregular period of time, receives its average proportions of wet and dry weather.

I am disposed to think, that the alterations continually in progress on the earth's surface, particularly those of draining the soil, and of clearing and planting forests, together with the extension of land in certain quarters, and its diminution in others, are the principal causes of that irregular variety in the wea-

ther of different years, and in the corresponding seasons of different years. Though such local causes at first affect only the weight, hygrometric condition, and temperature of the atmosphere immediately incumbent, still, by modifying and altering the direction and force of the winds, they ultimately give birth to general and widely extended results. And the effects produced in one year, or in one season of the year, have an influence in diversifying the meteorological character of those that follow. I am also inclined to think, that the weather in different years has a constant tendency to assimilate; and that, provided there were no such changes as those above-mentioned in progress, the weather, in corresponding seasons of the year, would ultimately become exactly alike. If these opinions be correct, it is obvious, that, as changes are continually going on with unequal degrees of rapidity, on different parts of the earth's surface, the causes which disturb the uniformity of the weather in different years, must be ever-varying. Hence, cycles, or an exact periodical recurrence of the same kind of weather, after any given number of years, need never be expected to take place. And as the unusual magnitude of any particular wave, is occasioned by the union and coalescing of smaller undulations; so summers and winters remarkable for heat or cold, or any other peculiarity, may result, at irregular intervals, from the accidental co-operation of a favourable combination of antecedent, and existing circumstances, for producing the effect.

CHAPTER X.

OF RARE AND IMPERFECTLY UNDERSTOOD METEOROLOGICAL PHENOMENA.

We now come to treat of several atmospheric phenomena, some of which are but little, and others not at all understood. The following is a list of them in the order in which they are to be considered:—1st, The Ignis Fatuus. 2d, Falling Stars. 3d, Fireballs and Meteoric Stones. 4th, Dry Fogs. 5th, Halos, Mocksuns and Mockmoons. 6th, The Mirage and Unusual Refractions. And, 7th, The Aurora Borealis.

Of the Ignis Fatuus.—The meteor denominated Ignis Fatuus, is also known by the more familiar epithets of Will-o'-the-Wisp, and Jack-o'-the-Lantern. This meteor makes its appearance on very dark still nights, over boggy or marshy ground. It usually presents the appearance of a pale taper-looking flame; sometimes apparently at rest on the surface of the bog, but more frequently moving about from place to place, at the height of five or six feet above the ground. At times it becomes invisible, and shortly thereafter re-appears in the same, or some other place not very distant. It is said, but I question the truth of the statement, that it retires upon being approached, so that, even though followed, it can never be overtaken. Owing to this circumstance, together with that of the

marshy soil over which it makes its appearance, the ignorant have ascribed to it an imaginary existence, possessing the mischievous disposition of wishing to mislead travellers into dangerous boggy ground.

Though this meteor is certainly within the reach of examination, I am not aware that its nature has ever been chemically investigated, or even that it has been subjected to close inspection. Combustion consists, in most cases, of the chemical combination of a combustible substance, with the oxygen of the air, attended, in consequence of the condensation which thereupon ensues, by the evolution of heat and light. It is known that certain substances take fire at very low temperatures. Thus phosphorus undergoes a very slow combustion upon exposure to the atmosphere at ordinary temperatures, and its combustion becomes more rapid according as the warmth increases. From analogy, it has been supposed that the ignis-fatuus is an example of combustion at a low temperature, consisting merely of the chemical combustion of the oxygen of the air, with streams of some unknown phosphoric fluid issuing under peculiarly favourable circumstances, in a concentrated form, from boggy ground; and resulting from animal or vegetable matter, in an unknown stage of decomposition. According to this hypothesis, its extinction in one locality, and reappearance in another, together with its flitting about from place to place without being wholly extinguished, depends upon the streams of the phosphoric fluid ceasing to be sufficiently concentrated to support combustion at one place, and becoming sufficiently concentrated to do so at another.

It must be confessed, however, that the nature of this phenomenon is involved in much mystery; and were it only to gratify curiosity, demands investigation.

Of Falling Stars.—This meteor makes its appearance on rare occasions in all kinds of clear weather, but particularly during frost, and when there is little wind. It is seldom visible for more than one or two seconds, and is never seen but at considerable altitudes in the atmosphere. It exhibits a rapid progressive motion, its course being usually somewhat inclined downwards from the horizontal, and hence the name Falling Star.

The principal hypothesis advanced to explain this meteor, is that it results from a stream of combustible gaseous matter rising up from the earth, and taking fire at an altitude where the atmosphere becomes sufficiently dry, and free of aqueous vapour, to admit of its combustion. The direction of its motion is supposed to result from the conjoint influence of the tendency of the combustible fluid to ascend, with the horizontal movement of the atmospheric current. When the stream of combustible matter reaches the requisite altitude it takes fire, and combustion is propagated backwards against the wind, and somewhat inclined downwards in the course of the ascending stream of combustible matter. Its extinction is supposed to be owing to the increasing amount of aqueous vapour as it descends in the atmosphere.

The preceding hypothesis is exceedingly unsatisfactory. It is impossible that any stream of gaseous matter could rise from the earth to the altitude where this meteor usually makes its appearance, without

being completely intermixed with the atmosphere, and dissipated by the wind, even in the stillest weather that ever occurs. What is called a falling star, may therefore, be regarded as a phenomenon, which has hitherto frustrated all attempts at explanation.

Of Fireballs and Meteoric Stones.—No meteorological phenomenon is more incomprehensible than Fireballs, and the descent of Meteoric Stones. Fireballs present the appearance of globular bodies in a state of intense ignition, and moving with great velocity, apparently in a horizontal direction, at a great altitude above the surface of the earth. Their extinction is said to be attended with an explosion resembling thunder, which is more or less loud, according to the distance of the observer from the place where it occurs. The explosion is immediately followed by the descent of what are called aerolites, or meteoric stones, which are of all different magnitudes from the weight of a few grains, to that of perhaps a hundred pounds. These products of fiery meteors, though somewhat rare, appear to have fallen at intervals in all ages and climates, for nearly two thousand years past, and probably also, had records of them been kept, in all anterior times. All those that have been examined present a similar structure and appearance. Upon being chemically analyzed, their elementary constituents are found to be nearly alike; and their specific gravity, relative to that of water, varies only from about 3.6 to 3.7. By way of sample, we subjoin the analysis by Vauquelin, of one of three stones which fell in France, in the commune of Char-

sonville, in the department of the Loiret, and neighbourhood of Orleans :—

Silica,	38.4
Alumine,	3.6
Lime,	4.2
Magnesia,	13.6
Iron,	25.8
Nickel,	6.
Manganese,	0.6
Sulphur,	5.
Chrome,	1.5
	98.7

The fall of the stones above analyzed, occurred on the 23d of November, 1810, about half-past one o'clock, P.M., and was accompanied by a series of detonations and reverberations, which lasted some minutes. The detonations are said to have been as loud at Orleans, Montargis, Salbri, Vierzon, and Blois, as at the place where the stones fell; and considerable alarm was excited, from the apprehension that they were occasioned by the blowing up of a powder magazine. These stones were precipitated perpendicularly. No luminous meteor, or visible fireball, preceded their descent,—a circumstance probably owing to the influence of the intense light of the sun, in obscuring one that was comparatively feeble. One of them took the ground at Montelle, but was never discovered; and of the other two, one fell at Villenoi, and the other at Moulin-Brulé, all of which places are within the distance of a mile. One of the stones weighed about twenty pounds, and made

a hole in the ground just large enough for its admission in a perpendicular direction, driving up the earth to the height of eight or ten feet. It was taken out half an hour after, when it was still so hot that it could scarcely be held in the hand, and it had a strong smell of gunpowder which it retained till it was quite cold. The second formed a similar hole three feet deep, weighed forty pounds, and lay fourteen hours in the ground before it was extracted, when it was quite cool. Both these stones were shapeless masses, irregularly rounded at the projections. The day on which they fell was remarkably calm and serene, and not a cloud appeared above the horizon.

A variety of hypotheses have been advanced, in order to account for the origin of meteoric stones. According to one of these, meteoric stones are missiles projected from volcanoes in the moon. This extravagant hypothesis is countenanced by calculations of La Place, Poisson, Dr Hutton, and others, by which it has been demonstrated, that a heavy body, projected with a velocity of 6000 feet in a second, may be driven beyond the sphere of the moon's attraction into that of the earth.

The greatest initial velocity ever communicated to a ball by gunpowder, is little more than 2000 feet per second ; and owing to the resistance of the atmosphere, the velocity of the ball rapidly diminishes as it recedes from the mouth of the gun. Now, it can hardly be supposed, that volcanic action could ever communicate to stones, a greater initial velocity than gunpowder confined in the barrel of a gun, can be made to communicate to a ball. And the attrac-

tion of the moon, even upon the supposition that it is not surrounded by an atmosphere, may be supposed to diminish the initial velocity of stones projected from lunar volcanoes as rapidly, as the resistance of the air diminishes the velocity of balls projected from a gun. Hence, to conclude that stones are projected from lunar volcanoes with such inconceivably greater force and velocity, as to enable them to pass through the space of 6000 feet in a second, in direct opposition to the moon's attraction, is an extravagant conception, refuted by all analogous facts with which we are acquainted. And a hypothesis which rests upon such a basis, must be regarded as fanciful and imaginary, and altogether unworthy of attention.

Another hypothesis much more extravagant than the preceding, is, that meteoric stones are small central fragments of a large planet, that once revolved round the sun between the orbits of Mars and Jupiter, but which is supposed to have exploded in some former age. According to this hypothesis, the four small planets denominated Juno, Pallas, Ceres, and Vesta, are four large fragments of the exploded planet. And meteoric stones, which have been occasionally falling on the earth's surface from time immemorial, are small central fragments, projected with such force as to be driven beyond the attractive influence of the large ones; and which, since the time of the explosion, have been wandering about through space, and occasionally falling upon the other planetary bodies of the solar system, when they accidentally happened in their peregrinations, to come within the sphere of their attraction.

This hypothesis consists of an improbable supposition, founded upon another improbable one. The arguments adduced to show that the explosion of a large planet gave birth to the above-mentioned four small ones, are somewhat analogous, and nearly as unsatisfactory, as those by which Buffon endeavoured to support his wild theory, that the whole planetary system consists of fragments struck off from the sun, at one and the same time, by the collision of a comet. This opinion Buffon conceives is proven by the fact, that all the planets, as well as their satellites, revolve round the sun nearly in the same plane, and in the same direction, viz., from west to east, round their axes, as well as in their orbits. The author of the hypothesis we are considering, ridicules the one first noticed as being romantic. But it is certainly more romantic, to suppose the existence of a volcanic force so great as to explode a planet, so that its parts could never afterwards reunite by the force of attraction, than to suppose that stones could be projected from a lunar volcano, with a velocity of 6000 feet in a second.

But admitting, for the sake of argument, that a planet did explode several thousand years ago, (though that is a very unlikely circumstance,) and that small central fragments, in consequence of being projected with great force, were driven beyond the sphere of attraction of the large ones, which have kept pretty nearly in their former orbit, it is an exceedingly extravagant idea, to fancy that meteoric stones, which have been falling at recorded intervals for nearly 2000 years back, can be small detached portions of the exploded

planet flying about yet, and falling upon the earth as numerously as ever. When the extremely small attractive force of the earth, relative to that of the sun is considered, one would suppose, that if those small fragments ceased to revolve round the sun in orbits, according to the ordinary principles of other planetary bodies, they must all very soon have fallen into the sun by the force of its attraction, and that none of them could have struck the earth, unless, in the course of its annual revolution, it had accidentally been in a proper position for intercepting some of them in their descent towards the sun. But to suppose that small fragments of the exploded planet should have deviated so far, and yet so slowly, and irregularly, from their original orbit, as to continue falling upon the earth at intervals for such a length of time, is a hypothesis too chimerical and extravagant to gain any belief.

Another hypothesis is, that meteoric stones are thrown up by terrestrial volcanoes. If it is thereby meant, that the stones are thrown up in the same solid state as they descend, the hypothesis is disproved by the fact of their having fallen at many hundred miles' distance from any volcano; and at times when no eruptions in the nearest volcanoes had occurred for a great number of years previous.

The following hypothesis by Playfair is more plausible than any of the preceding. And as it is given with less pretension to accuracy than any of the others, we subjoin it in his own language:—

"In the absence of all analogous appearances, it is perhaps unphilosophical to offer any explanation

of the meteoric stones. We would only suggest as a mere possibility, that gaseous substances may be thrown up into the air, from the numerous volcanoes on the earth's surface, and may carry with them certain elements of metallic and stony bodies from the mineral regions; these, while floating about in the atmosphere, may sometimes be collected in considerable quantities into one place, where being subjected to electric or galvanic action, they are united into a solid mass. The fact that many of these stones have fallen during thunderstorms, seems to limit the place of their formation to the atmosphere of the earth."

That aerolites originate in the higher regions of the atmosphere, seems probable from the following facts:—1*st*, They never exceed a moderate magnitude. 2*d*, They are uniformly preceded by, and originate out of a fiery meteor, which is seen moving horizontally with great rapidity, and sometimes for a very great distance, in the higher regions of the air. 3*d*, However far the fiery meteors supposed to give birth to meteoric stones may travel horizontally in the higher regions of the air, they always explode, and are extinguished at a considerable altitude; and yet that altitude is so limited, that the explosion is usually heard at the earth's surface.

Upon the supposition that aerolites originate in the higher regions of the terrestrial atmosphere, it is certain that the metallic and earthy substances of which they are composed must exist in the gaseous state, in the elevated regions where they are formed. That the substances of which meteoric stones are composed are derived from the subjacent earth, seems probable

from the fact, that the relative proportions of their several constituents, bear a general relation to those in which these constituents are found, as component parts of the crust of the earth. Thus silica, which is the most abundant element in meteoric stones, is also the most abundant element in the strata composing the crust of the earth. And iron, which is the second most abundant element in meteoric stones, is also a very abundant element in the terrestrial strata. On the other hand, chrome and maganese, which are the least abundant elements in meteoric stones, form but a very small proportion of the crust of the earth.

The first difficulty in explaining the phenomena exhibited by aerolites, is to show how the metallic substances of which they are composed get translated into the elevated regions of the atmosphere. So far as chemical analysis may be depended upon, no such substances are to be found in the air within twenty thousand feet of the level of the sea. And the fact, that fireballs which give birth to meteoric stones, are never seen in the atmosphere near the earth's surface, so far confirms the results of chemical analysis, that the elementary constituents of meteoric stones do not exist in the lower aerial strata. Recent chemical investigations have demonstrated, that, besides the metals, all the earthy substances contained in meteoric stones, are compounds, with the exception of sulphur, and consist of different metallic bodies, united with a greater or less proportion of oxygen. And though chemical analysis has hitherto failed in decomposing metals, it is by no means improbable that they also are compounds.

Now, unless it be supposed that the elements of meteoric stones constantly exist in the gaseous state, either intermixed with the air in its more elevated regions, or that they form a separate and specifically lighter atmosphere beyond the boundaries of that with which we are acquainted, it is obvious, that, before ascending, they must first be volatilized, and converted into the gaseous state. And as a great degree of heat is necessary to produce such an effect, Playfair's suggestion, that the elements of meteoric stones may be carried up into the atmosphere by means of volcanic agency, may be regarded as not only a mere possibility, but as a hypothesis by no means improbable.

Another difficulty attending the phenomenon of fireballs, is to account for the great horizontal velocity with which they always appear to move. It is presumable that the intense ignition to which they seem subjected, is owing to the heat and light evolved during the condensation of the materials of which the meteoric stones are composed. And it is possible that the rapid horizontal motion of fireballs, may be owing to the progressive propagation of the chemical combination, and condensation of those materials; and this may result from the affinity of the substances undergoing combustion and condensation, for those that remain uncondensed. The nature of the explosion upon which the extinction of the meteor, and the descent of the meteoric stones ensues, has hitherto received no explanation. Indeed, owing to the unattainable elevation at which fireballs make their appearance, all the knowledge we need ever ex-

pect to obtain concerning their nature and origin, is limited to very doubtful conjectures. Fireballs, and the descent of meteoric stones, may, therefore, be regarded as phenomena which do not admit of being satisfactorily accounted for.

Of Dry Fogs.—Another meteor, which, if the description given of it be correct, (but which is very doubtful,) has never received any satisfactory explanation, is what is called Dry Fogs. We subjoin the description given of this meteor by Dr Prout in his Bridgewater Treatise, together with part of the commentary thereupon, which we consider the only unphilosophical passage in that deservedly popular work.

"In the year 1782, and still more in the year following, a remarkable haze of this kind extended over the whole of Europe. Seen in mass, this haze was of a pale blue colour. It was thickest at noon, when the sun appeared through it of a red colour. Rain did not in the least degree affect it. This haze is said to have possessed drying properties, and to have occasionally yielded a strong and peculiar odour. It is also said to have deposited in some places a viscid liquid, of an acrid taste, and of an unpleasant smell. About the same time, there were in Calabria and in Iceland, terrible earthquakes, accompanied by volcanic eruptions. These earthquakes and eruptions were supposed to have been connected with the haze. Indeed it has been generally remarked, that such a condition of the atmosphere has been usually preceded by an earthquake, either in the same, or in some adjoining country. The dispersion of this haze in the summer of 1783, was attended by severe thunder-

storms. As might be expected, the general state of health has, for the most part, been deranged during the continuance of these phenomena. Simultaneously there have been epidemic diseases of various kinds. Thus in the above mentioned years, 1782 and 1783, an epidemic catarrh, or influenza, prevailed throughout Europe; affecting not only mankind, but likewise other animals.

"The nature of the matter thus diffused through the atmosphere is quite unknown. It may at different times be not less various than the character of the epidemics to which it gives origin."

I am inclined to think that the preceding description of a dry fog is exceedingly exaggerated, and incorrect; and I suspect must have been extracted by Dr Prout from some very inauthentic source. Many old people are still alive who must recollect the phenomena, if they were so remarkable, as they are said in the above extract to have been. But what convinces me that the description is inaccurate, is, that though it is only 52 years since this dry fog occurred, I never heard it mentioned by any person who had witnessed it; and never saw it noticed by any author till I read it in the Bridgewater Treatise. At all events, there is no satisfactory evidence adduced, that the epidemic catarrh which prevailed in 1782 and 1783, was produced by the dry fog. Judging from the fact, that influenza frequently becomes epidemic in seasons when no dry fogs make their appearance; and except in the above instance, is never recorded, so far as I am aware, to have been accompanied with a dry fog, it is presumable, that they have no connection. Influ-

enza is usually supposed to be produced by exposure of the body to great and sudden, and sometimes, to frequently repeated changes of temperature. In this climate, it generally occurs during east or north-east winds, in the months of April and May; and when the sky for the season of the year, is on an average clearer, and freer of clouds than usual. In the above circumstances, the vicissitudes of temperature to which the body is exposed, are usually greater than at any other season of the year. When exposed to the sun, and sheltered from the breeze, the heat is then felt to be very considerable. But during night, or when exposed to the breeze, and sheltered from the sun during day, the dry atmosphere, by promoting evaporation, rapidly extracts the heat from the body, and produces the feeling of cold. The vicissitudes in the atmospheric temperature are farther augmented, by alternate changes in the direction of the wind, from south-west to north-east, and the contrary. Such changes of wind are of frequent occurrence, in this climate, during April and May; and are attended by a greater and more sudden alteration of temperature, than at any other period of the year. In seasons remarkable for the above combination of circumstances, influenza is apt to become epidemic.

From the great numbers seized about the same time with this epidemic, it has been conceived by some to be infectious. But from the fact of its following no progressive route traceable on a map, and frequently becoming simultaneously epidemic, not only in one, but in a number of neighbouring, and sometimes even in distant countries; and from its

affecting the most sequestered and thinly peopled districts, equally with those where the population is densest, and the thoroughfare greatest; the appearances of infection have, with more propriety, been ascribed to the circumstance of great numbers being exposed to the same causes of disease.

At Philadelphia, in the beginning of December, 1831, a remarkably prevalent epidemic of this kind occurred, which was said to be produced by an unusually sudden and great change of temperature. The following is an extract of a letter from a relative of mine, describing its effects:—

"Philadelphia, 10th December, 1831.—The winter has set in here so suddenly, that firewood has risen, in a few days, from 6 to 12 dollars a cord. Today and yesterday are milder than it has been, and the ice in the Delaware is still moving during part of every tide. There never were so many bad colds before in this place as now. It is supposed by some that 50,000 people are confined to the house with them. The banks and other public offices find the utmost difficulty to get along from so many of their hands being confined at home. Out of a class of medical students, which consists of 100, only 16 are attending the lectures; and it is said that the legislature of New Jersey have adjourned on the same account."

Dr Prout, following up his notion of different epidemic diseases being produced by the presence of foreign materials in the atmosphere, ascribes the appearance of that malignant and infectious species of Asiatic cholera in this island in 1831 and 1832, and

which originated in India in 1817, to a cause of this kind. In proof of which, he says, "On a particular day, the ninth of February, 1832, the weight of the air suddenly appeared to rise above the usual standard." And it retained its augmented weight during the whole time his experiments were carried on, viz. for about six weeks thereafter. In explanation, he says, "There seems to be only one rational mode of explaining this increased weight of the air at London, in February, 1832; which is by admitting the diffusion of some gaseous body through the lower regions of the atmosphere of this city, considerably heavier than the air it displaced. About the ninth of February the wind, which had previously been west, veered round to the east, and remained chiefly in that quarter till the end of the month. Now, precisely on this change of the wind, the first cases of epidemic cholera were reported in London, and from that time the disease continued to spread. That the epidemic cholera was the effect of the peculiar condition of the atmosphere, is more, perhaps, than can be safely maintained; but reasons which have been advanced elsewhere lead the writer of this treatise to believe, that the virulent disease, termed Cholera, was owing to the same matter which produced the additional weight of the air."

Whether the increased weight of the air, which Dr Prout alludes to in the above quotation, was owing to a diminution in the amount of its aqueous vapour, or to increased atmospheric pressure, or to some other cause, may be left undetermined. But hardly any person will believe that epidemic cholera in London, or in any

other part of Europe, was spread by the wind, or produced by any other means, than those by which other infectious diseases are communicated. Indeed, if I recollect right, the first case of cholera in London was traced to a vessel which had just arrived from Sunderland, or Newcastle, where the disease then was. It would be deviating unwarrantably from our subject to enter into any lengthened digression on this point. We will only therefore add, that owing to the shortness of the interval between imbibing the infection by communication with the sick, and the symptoms of disease ; and to the circumstance of the disease never appearing in any instance, but where such communication with the sick, as is known in other infectious epidemics to be capable of communicating infection, had previously occurred ; there never perhaps appeared any distemper on the face of the earth, of which there was such innumerable and incontestable evidence of its being communicated from man to man by infection ; and by infection alone. And that the direction of the wind, or the condition of the atmosphere, (except within the apartments or dwellings of persons labouring under the disease, or in places where individuals suffering under the premonitory symptoms had previously been,) had no influence in spreading it whatever, was equally satisfactorily demonstrated.*

* In this island, by far the greatest number of persons who were seized with cholera, had either previously visited, or lived in the same house with a cholera patient. Many were infected (as is the case with dysentery,) by visiting the necessaries, which persons labouring under the premonitory symptoms of this distemper frequented. Infection was also communicated by the clothes and

Of Halos, Parhelia, or Mocksuns, and Mockmoons.—In very high latitudes, and sometimes in temperate latitudes during cold weather, what are called Halos, and Parhelia, or Mocksuns, and Mockmoons, are on rare occasions seen. A halo consists sometimes of one, and sometimes of two concentric circles of coloured or refracted light, such as that of a rainbow, the one forming an angle of about 23½ degrees, the other an angle of about 47 degrees with the sun, or moon. In different parts of these concentric circles, and chiefly in opposite points at a similar altitude with the sun, bright spots of unrefracted light are seen, which have received the names of mocksuns, or mockmoons, according as the light is received from the sun or from the moon, during the appearance of the halo. From these bright spots diverging horns, or small segments of an external circle of refracted light, has on some occasions been seen. Sometimes the parhelia have conical tails of coloured

bedding of persons who had died of the disease. And in some very rare instances, there is reason to suspect, (though this point is not altogether certain,) that infection was communicated by persons who had been visiting the sick, to others who had had no known communication with them ; and this too, without the persons who transported the infection, (perhaps on their clothes,) ever being seized with the disease. I am inclined to think, that the external atmosphere, even in the densest parts of cities, or in the neighbourhood of cholera hospitals, never became so strongly impregnated with the infectious effluvia, as to communicate disease in one single instance. Similar observations are probably applicable to all other infectious diseases communicated by means of effluvia diffused through the atmosphere, and emanating originally from the lungs, skin, or discharges of patients labouring under like diseases.

light, turned away, like the tail of a comet, from the true sun.

A variety of theories have been advanced in order to explain the nature of a halo. In these it seems to be generally agreed, that the phenomenon is produced by the sun or moon's light, being refracted by numerous small, and perhaps primary crystals of snow, or frozen vapour, of similar configuration, floating in the air. The quantity of these crystals though considerable, is not conceived to be so great as to darken the air, or obscure the light of the sun to any very palpable extent. Now it is obvious that if these crystals be all of the same determinate configuration, they will all float in a still, or nearly still atmosphere, in a similar position, viz. with their bases, or heaviest sides undermost; and consequently, will all refract the light of the sun in the same degree. Hence the reason, that the halo or coloured circle of refracted light, always appears at the same distance from the sun.

Parhelia, or mocksuns, and mockmoons, have been supposed to be produced by numbers of those floating crystals of snow or frozen vapour, being arranged in such a manner at particular points, that the sun or moon's light is transmitted in a concentrated, instead of a refracted form. This opinion is in all likelihood erroneous. Indeed, the circumstance of parhelia always making their appearance at the same points of the halo relative to the position of the sun, demonstrates that they are not produced by any accidental, or different arrangement of the floating crystals, from what exists in other parts of the atmosphere.

The phenomenon probably depends upon some unexplained influence of frozen crystals in polarizing light. The number of theories however advanced in order to explain this, and the preceding phenomena, and which all differ more or less from each other, show that they are by no means perfectly understood.

As the phenomena of halos, and mocksuns, and mockmoons, are more connected with the science of optics, than with that of meteorology, it would be digressing too far from our subject, to enter into any detailed account of the various and somewhat obscure theories, which have been advanced in order to explain them.

Of the Mirage, and Unusual Refractions.—This is another subject that has been slightly adverted to in meteorological writings, but which more strictly belongs to the science of optics.

Refraction of the line of vision is familiarly exemplified in the following experiment. Let a shilling be placed in the bottom of an empty basin situated on the floor, and let a person stand just so far distant from it, as to be unable to see the shilling. If water be then slowly poured into the basin, the shilling though it does not change its real position, gradually comes more and more into the view of the spectator. This is owing to the line of vision being refracted somewhat downwards at the surface of the water; or, speaking more correctly, to the rays of light reflected by the shilling, being refracted downwards towards the horizontal, upon emerging from the surface of the water.

Different substances appear to have different powers

in refracting light, and each substance, by having its density increased, has its refracting power thereby augmented. Aqueous vapour, in an imperfectly dissolved state, (such as when it exists in the state of haze or mist,) seems to have more power in refracting light than air; and both air and mist, (provided the latter be not so dense as to obscure the view of distant objects,) have their powers of refracting light augmented by increase of density. Besides, the optical illusion produced by the refracting power of imperfectly dissolved aqueous vapour, is farther assisted by the circumstance of the colour of the light reflected by the haze being so similar to that of water, as to be indistinguishable from it. Hence vessels sailing on water, when seen refracted by haze or mist, appear as if sailing through the air; and distant objects, raised by the refraction of aqueous vapour above their actual level in the horizon, appear as if surrounded by water. And it need hardly be remarked, that every object appears to the spectator, to be in the direction in which the rays of light reflected, or emanating from it, enter the eye. Of course, if the rays of light be refracted before entering the eye of the spectator, the object appears not in the direction in which it actually is, but in the direction in which the refracted rays emanating from it enter the eye.

The phenomena of the mirage, and of unusual refractions in general, are explained according to the preceding principles, either by supposing that the atmospheric strata, near the earth's surface, are unequally heated, and therefore unequal in density; or by supposing, that they contain unequal proportions

of mist or imperfectly dissolved moisture. Supposing the atmospheric strata, within a few yards of the surface of the earth, to be free of haze, while immediately above that altitude, there is a slight degree of haze arising from moisture not thoroughly dissolved, but not so dense as to obscure the view of distant objects. In this case, a distant object, viewed along a level surface, such as a vessel at sea, will appear in its natural position, while, owing to the refracting power of the undissolved moisture above, another figure of the vessel will appear as if sailing in the air, and will seem to be diminished or increased in height, or in different degrees distorted, or even inverted, according as the different strata, and portions of the mist by which the rays of light emanating from the vessel are refracted, increase or diminish in density. According to similar principles with that of the image of a vessel sailing in the air, distant objects are sometimes seen on land by means of the refractive power of imperfectly dissolved aqueous vapour, when slight eminences intervene between the object viewed and the spectator.

In Egypt, and in neighbouring level sandy deserts, the mirage sometimes assumes the appearance of a sheet of water inundating the ground near the horizon. This effect is supposed to be owing to refractions, produced partly by the influence of the rarefaction of the atmosphere being greatest near the heated ground, and diminishing upwards, and partly to the unequal proportions of imperfectly dissolved moisture, which these various atmospheric strata contain.

Of the Aurora Borealis, or Northern Lights.—This phenomenon makes its most brilliant appearances in high latitudes, and during the cold season of the year. When seen in this climate, it usually presents the appearance of a faint illumination of the northern parts of the sky, somewhat resembling the departure of twilight; and frequently, though not always, seems to emanate from a dark cloud near the northern horizon. Sometimes it presents the appearance of arches of striated light, commonly called Streamers, of about the breadth of a rainbow, originating near the northern horizon, and stretching across the sky, in a southern direction, to the zenith, and sometimes much beyond it. These streaks are sometimes observed gradually vanishing, and again in the same, or some other place, suddenly bursting out, as if some luminous matter were rushing from the north towards the south, in the higher regions of the atmosphere. The other more equally diffused portions of the meteor, which present the appearance of a faint light in the sky, are subject to constant variations in brightness; sometimes gradually disappearing in one quarter, while they are becoming more vivid in another. When the meteor becomes remarkably bright, the expanse of light in the sky, is sometimes seen to spread and contract, in consecutive flashes, with such rapidity, as to maintain a visible waving and undulatory movement. Sometimes when this meteor is seen to expand very suddenly over the zenith, particularly in dry, clear, cold weather, a hissing, rushing noise is heard. The variation of the needle is also affected by it, its north pole being usually somewhat

diverted from its regular position, towards where the meteor is brightest.

The altitude of this meteor above the surface of the earth, has been variously estimated by different individuals. Bergman, from a mean of thirty computations, makes the height of this phenomenon to be 468 English miles. Boscovich calculated the height of an aurora borealis, observed on the 16th December, 1737, by the Marquis of Poleni, to have been 825 miles. Mairan supposed the far greater number of auroræ to be at least 600 miles above the surface of the earth. Euler assigned them an elevation of several thousands of miles; and Dr Blagden limits their height to about 100.

Various theories have been advanced to explain this phenomenon. According to Kirwan, it is owing to the combustion of hydrogen gas, which he supposes to exist in great quantity in the higher regions of the atmosphere, and which, he conceives, is set on fire by electricity. This theory is founded upon no evidence whatever, and is disproved by various facts. Air obtained at the height of 22,960 feet has been analyzed by Gay Lussac, and hydrogen has not been detected to be one of its elements, save as a constituent of aqueous vapour. And even the proportion of aqueous vapour, contained in the atmosphere, has been found to decrease so rapidly upon ascending perpendicularly, that at the height of 22,960 feet, its mean amount, relative to the other ingredients of the atmosphere, is only about one-eighth part of what it is at the surface of the earth.

The supposition that hydrogen gas exists in quan-

tity in the higher regions of the atmosphere, is farther disproved by the fact, that hydrogen, as well as all other gaseous substances, when in free communication with the air, or with each other, have a tendency to intermix together so completely, that each proportion of space contains an equal amount of each of them. Thus if two glass globes, the one above the other, and communicating by a stopcock, be severally filled with different gases, and the stopcock turned, so that they are allowed to communicate, they gradually and completely intermix, even though the specifically lighter gas be contained in the upper globe. For instance, suppose the upper globe be filled with hydrogen, the lightest of all gases, and the lower one filled with common air; if the stopcock be turned so as to allow them to communicate, they become in a short time so completely intermixed, that each globe is found to contain an equal proportion of hydrogen, intermixed with an equal proportion of common air. Now, reasoning from the analogy of the above experiment, it must be inferred, that hydrogen does not exist either as a separate gas beyond the boundaries of the atmosphere with which we are acquainted, nor as a large constituent of the more elevated aerial strata. Even supposing that by some means or other a stratum of hydrogen was suddenly spread over the summit of the atmosphere, it must be inferred according to the same analogy, that it would very soon be intermixed so completely with the subjacent aerial strata, that each proportion of space would contain an equal quantity of it, relative to the proportions of the other atmospheric elements. When

these observations are considered in conjunction with the fact, that hydrogen, except as an element of aqueous vapour, does not exist as a constituent of the atmosphere lower than the altitude of 22,960 feet, which is the greatest height ever reached by man, it may be inferred that it does not exist above that elevation.

We will only farther remark, that if Kirwan's theory was correct, it is presumable, that the phenomenon of the aurora would be of equally frequent occurrence, and equally brilliant, in intertropical climates, as it is in high latitudes. This, however, is not the fact. The aurora, at least in its more brilliant exhibitions, is confined almost exclusively to very high latitudes; and in intertropical climates it is wholly unknown.

According to Dr Halley, the aurora is owing to the circulation of the magnetic effluvia of the earth from one pole to the other. And Beccaria, who supposed that the electric fluid circulated in a similar manner from pole to pole, conceived that the aurora was produced in certain states of the atmosphere, when the circulation of the electric fluid becomes less elevated than usual. Both these theories have been disproved by the observations of Mr Forster, by which it appears, that the columns of the aurora shoot up towards the zenith from the southern polar regions, in the same manner as they do from the northern.

A modification of the theory last mentioned, is, that the aurora is produced by the passage of the electric fluids, in the higher regions of the atmosphere, from the polar towards the equatorial latitudes. Accord-

ing to this theory, electricity is constantly circulating through the terrestrial strata from the equatorial to the polar regions. It is then supposed to ascend from the earth, and return in the higher regions of the atmosphere to the equatorial latitudes, where its circuit is completed by again descending to the earth. This theory is free from the objections urged against the others, and is supported by the analogy of certain electric phenomena that can be artificially exhibited. "Thus, if a glass tube, resembling a Florence flask in size and shape, be exhausted of air by means of a stopcock and syringe fixed to its mouth, and be then excited by friction, it will appear filled with a pale light, resembling the aurora borealis, which will go and come at intervals, sending forth brilliant flashes, exactly as this meteor does in the heavens. If either end of the flask be presented to the conductor of an electrical machine, the other being held in the hand, a constant stream of pale light will be transmitted through it proceeding from the conductor. Mr Canton also contrived to exhibit an imitation of the aurora borealis, by means of electricity transmitted through the Torricellian vacuum formed in a glass tube, about three feet long, and hermetically sealed. When one end of the tube is held in the hand, and the other applied to the conductor of an electrical machine, the whole tube is illuminated from end to end, and will continue luminous for a considerable time after it has been removed from the conductor. If after this, it be drawn through the hand either way, the light will be uncommonly intense, extending without the least interruption from one hand to the other, even through-

out its whole length. By this operation, however, a great part of the electricity is discharged; nevertheless the tube will flash at intervals, if held at one extremity and kept quite still, but if it be grasped by the other hand at the same time in a different place, strong flashes of light will hardly ever fail to dart from one end to the other, which will continue for twenty-four hours, and longer, without any fresh excitation. An arched double barometer, of a considerable height, exhibits these phenomena in a still more striking manner."

The striking analogy between the luminous appearances exhibited in the preceding experiments, and that of the aurora borealis, affords strong grounds for believing, that this phenomenon is produced by the passage of electricity, through the elevated and highly rarefied strata of the atmosphere, from the polar towards the equatorial regions. This opinion is farther confirmed by the circumstance of the magnetic needle being affected by a brilliant aurora, in the same manner as it is by the approach of a thunder-cloud. And when it is considered, that coldness and dryness are favourable to the accumulation of electricity in bodies, the hypothesis under consideration is also supported by the fact of this phenomenon, only making its appearance in high latitudes, and in winter, rather than in summer.

Upon the preceding theory it may be remarked, that neither electricity nor any other fluid can set itself in motion; and though set in motion, could not continue to pervade either the earth or the atmosphere, or any other obstructing medium, without the

agency of some force, or propelling power to maintain the motion. The principal defect therefore in the above theory, is, that no explanation is given how the circulation of electricity originates, and is maintained in the manner described; or how the aurora in this climate, should be visible only on rare occasions.

In what follows, we do not pretend wholly to supply what is wanting to render the above theory satisfactory; but we will endeavour to throw out some hypothetical suggestions, which, to a limited extent, will obviate objections, and may ultimately lead to a thorough explanation of the whole phenomena.

According to the principle we formerly advanced when treating of the cause of thunder in the fifth chapter, viz., that heat and electricity are mutually repellent; the capacity of any body for electricity increases as its temperature sinks, and diminishes as its temperature rises. In the former case, it becomes undercharged, and attracts electricity; in the latter, it becomes surcharged, and gives off electricity. Agreeably to this principle, the capacity of the atmosphere, and the subjacent terrestrial strata for electricity, and the amount of it therein contained, increases from the equatorial to the polar regions. Now, all that is necessary in order to account for the origin and maintenance of an electric current, such as that which has been conceived to exist in order to explain the phenomenon of the aurora, is to show how any portion of the earth or atmosphere in the direction of the electric current, should have a tendency to become undercharged with electricity, so that the electric fluids

should be attracted in the supposed direction of the current.

When treating of winds, it was stated, that their most general cause, is the gradual diminution in the mean annual temperature of the atmosphere, from the equatorial towards the polar regions. And, if the mean for the whole earth be estimated, that the prevailing direction of the wind in the upper half of the atmosphere, is from the equatorial towards the polar latitudes, while the prevailing direction in the lower half, is from the polar towards the equatorial. Now, as the prevailing wind in the upper half of the atmosphere from the equatorial towards the polar regions, is becoming gradually colder, it may be conceived to be constantly more or less undercharged with electricity, in consequence of its electric capacity increasing faster than it is supplied by the non-conducting, or rather the very slow-conducting dense atmospheric strata underneath. Hence, an electric current in the higher regions of the atmosphere, from the polar towards the equatorial regions, ought to be produced, by the tendency of electricity to diffuse itself equally among bodies, according to their several affinities for it. The aerial particles, as their temperature gets reduced in their progress northwards in the higher regions of the atmosphere, have their capacity for electricity thereby increased. Consequently, the mutual repulsion of the particles of electricity accumulated in the polar latitudes of the earth and atmosphere, gives rise to an electric current towards the equatorial latitudes. And the reason why the visible, and concentrated portion of this electric current, is restricted to

great altitudes in the atmosphere, may be owing, to the increasing power of the air in conducting electricity as its density diminishes. Near the earth's surface, the density of the air is so great, that electricity can only pass through it very slowly: whereas, at great altitudes, its density is so much reduced, that electricity may pass through it with considerable facility.

The abstraction of a portion of the electricity from the elevated regions of the atmosphere above the polar regions, must cause electricity to ascend from the subjacent terrestrial strata, in order to compensate for the deficiency of electricity created by the electric current towards the south, which we have supposed to give rise to the aurora. Upon similar principles, the passage of electricity in the polar regions from the earth to the higher regions of the atmosphere, must cause the earth in these latitudes to be undercharged with electricity, relative to its capacity for it. Hence, an electric current through the terrestrial strata from the equatorial to the polar regions will be produced. And this in its turn, will create a deficiency of electricity in the terrestrial strata of the equatorial regions. The reduction of temperature which the atmosphere undergoes, and the consequent increased electric capacity which it acquires, in ascending from the earth's surface, upon the approach of the sun to the zenith, and which we supposed in the fourth chapter to be the chief cause of the rainy season in intertropical climates, enables us to understand how the electric current is completed, in accordance with the theory of the aurora borealis, which we are now endeavouring to elucidate. The electric current

in the higher regions of the atmosphere from the polar to the equatorial latitudes, upon reaching the intertropical zone where the atmosphere is ascending, will be attracted downwards towards the earth, by the increasing capacity of the atmosphere, and also of aqueous vapour, for electricity, as their temperature is reduced in rising from the heated surface of the earth. And this descending electric current, is possibly one of the sources whence the clouds in intertropical climates, are supplied during the rainy season with electricity.

Thus we see that the force or propelling power which originates, and maintains the electric current before described, may be owing to attraction exerted upon electricity by the increasing capacity of the atmosphere for it, as its temperature gets reduced upon rising from the earth's surface in intertropical climates; and as its temperature gets farther reduced, in its progress from the equatorial to the polar latitudes, in the higher regions of the atmosphere. Hence the current of electricity so produced moves in an opposite direction to that of the atmospheric current, and only does so, when the wind blows from a warm towards a cold climate.

It may be objected to the view which we have given of the electrical current, that it ought to present a luminous appearance in rising from the polar latitudes of the earth to the higher regions of the incumbent atmosphere, in the same manner as it does in its passage in the higher regions of the air from the polar to the equatorial latitudes. In answer to this objection it may be remarked, that owing to the increasing non-

conducting power of the air, as its density augments in descending towards the earth's surface, the current of electricity is probably more concentrated in its passage to the equatorial latitudes in the higher atmospheric regions, than it is when rising in polar latitudes from the subjacent earth, to those elevated aerial strata. And hence, it may present a luminous appearance in the former circumstances, and not in the latter. Air is a non-conductor of electricity, and the denser, the drier, and the colder it is, the stronger do its non-conducting properties become. No substance however is possessed of such perfect non-conducting properties, as altogether to prevent the passage of electricity from one body to another, when the latter is electrically undercharged relative to the former. It is not improbable but the electric current in the higher regions of the atmosphere, is supplied with electricity in high latitudes, from a very large extent of the earth's surface. And the great extent of terrestrial surface from which it is supplied may compensate for the slowness, and smallness of the supply from any given portion thereof. Supposing that electricity ascends from every part of the earth's surface within the Arctic circle, we would have the ascending current of electricity diffused over a circle of the earth's surface, the diameter of which would be no less than 3266½ English miles. Whereas, the portion of the higher atmospheric strata, into which the current of electricity in its progress towards the equatorial regions is subsequently concentrated, may not exceed a few miles in perpendicular depth, and perhaps not so much.

In like manner, the reason why the aurora becomes less brilliant as it recedes from the polar latitudes, until it becomes altogether invisible, is probably owing principally to the circumstance of the electric current becoming diffused over a larger circumference, as it diverges from the polar circles towards the equatorial regions; and partly, perhaps, to the increasing temperature, on receding from the polar regions, augmenting the conducting power of the atmosphere; and thereby giving less obstruction to the electric current; and consequently causing less electric accumulation.

The sudden extension and bursting out of the aurora at particular places, and thereafter its becoming gradually less vivid, may be owing to the obstruction given to the electric current by the non-conducting properties of a cold, dry atmosphere. In such circumstances, it may be easily conceived that the electric fluids may, for a time, accumulate in high latitudes, till the increasing repellent power, mutually subsisting among the particles of electricity, enables them at length to force a passage from some projecting point through the obstructing medium. This is somewhat analogous to the manner in which portions of electricity accumulating in a thundercloud are discharged at intervals, by forcing a passage from a dependent part of the cloud to the earth, through the non-conducting atmosphere.

The extreme elevation assigned to the aurora by Bergman, Boscovich, Euler, and others, which we formerly mentioned, I conceive to be erroneous. Indeed the remarkable discrepancy between their esti-

mates, such as Euler supposing its elevation to be several thousand miles, and Blagden only 100, shows that the principles upon which the estimates are made, are not to be relied upon. Besides, as electricity meets with no obstruction whatever in passing through an entire vacuum, the irregular, and frequently interrupted movements, and sudden burstings forth of this meteor from particular projecting points, do not admit of any explanation, unless the phenomena presented, are the result of movements of the electric fluids within the limits assigned to the atmosphere, by which the earth is surrounded.

The hissing or whizzing noise which sometimes, and especially in high latitudes, accompanies the sudden bursts or eruptions of the aurora, I am disposed to ascribe, not as is usually done to the distant phenomena, but to the corresponding, and simultaneous movement of the electric fluids in the air around the spectator. The particles of electricity are mutually repellent. Of course, when a current of electricity in the higher regions of the air, suddenly supervenes the place where the observer is situated, all the electricity contained in the atmosphere underneath the electric current, is repelled towards the earth; and the whizzing or crackling noise heard, I conceive is produced by the passage of repelled electricity from one aerial particle to another. When the air is fully saturated with electricity, and when, from great coldness, dryness, and density, its non-conducting power is strongest, the whizzing noise should be loudest. And in opposite circumstances, the proportion of repelled electricity may be so small in quantity, or may

pass so easily to the earth, as to occasion no audible sound whatever.

Supposing the perpendicular height of the aurora to be only thirty or forty miles above the level of the sea, which is probably much nearer the truth than the previously stated estimates, it is obvious, that the hissing or crackling noise above alluded to, is not produced by what is occurring either at that, or any greater elevation, for the two following reasons.

1. Sound emitted by a sonorous body is less audible, according as the air around it becomes more rarefied. And when a body is surrounded by a perfect vacuum, its susceptibility of communicating sound ceases entirely. Of course, no sound audible at the earth's surface, can be produced by the vibratory movements of matter existing beyond the boundaries of the atmosphere. And even at the height of thirty or forty miles above the level of the sea, the air must be so rarefied, that, were all the artillery on earth simultaneously discharged at that altitude, no audible sound could reach the earth's surface.

2. It has been ascertained that sound travels at the rate of 1142 feet in a second, or about an English mile in four and a half seconds. Consequently, before sound produced at the height of 30 or 40 miles could reach the earth's surface, two or three minutes would elapse. Now, the fact which disproves the hypothesis that the hissing noise is produced at the height of 30 or 40 miles, is, that it is heard exactly at the same instant, that the rushing extension of the meteor towards the south is seen. Indeed, so simultaneously is the extension of the

meteor towards, or over the zenith seen, and the whizzing sound heard, and so distinct is the sound from every other, that no person can observe the concomitance without being impressed with the belief, that the sound is produced by the influence of the meteor. The only hypothesis, therefore, by which the two phenomena can be connected, is that which we have advanced, viz. to suppose that the whizzing sound is produced by a movement of repelled electricity in the air immediately surrounding the spectator, corresponding to, and produced by that in the higher regions of the atmosphere, which we conceive to be the cause of the aurora.

The fact of the aurora being visible only on rare occasions, may be owing to the electric current being sufficiently strong only under such a favourable combination of circumstances, as rarely occurs in this climate. And the chief of these circumstances, according to the hypothesis under consideration, is probably a rapid decrease from the polar to the equatorial latitudes, in the amount of electricity contained in the higher strata of the atmosphere, relative to their electric capacity; and which may be occasioned by a strong wind from the south, in the upper regions of the air. This may possibly be assisted by an unusual accumulation of electricity in the atmosphere in polar latitudes, relative to the atmospheric capacity in those regions for electricity; and which may be occasioned by a rapid rise of temperature, subsequent to an unusual degree of atmospheric dryness, coldness, and stillness. Such are all the hypothetical suggestions which we mean at present to advance, in order to

explain the phenomena presented by the aurora borealis.

We have now concluded our survey of the causes and principles of meteorological phenomena. In a variety of instances, the views and explanations advanced are new; but how far they are entitled to the character of being true, it is not for me to decide. When different explanations have been given of phenomena by different individuals, their relative degrees of probability, or improbability, have been impartially weighed and appreciated; and where opinions however universally received by meteorologists, appeared to be erroneous, we have not failed to call them in question. On various occasions, when meteorological facts have obtruded themselves, of which the explanation was either defective, or altogether wanting, we have either endeavoured, on the spur of the moment, to supply the deficiency, or admitted our incompetence to do so. Many of the explanations given may be objected to on account of their hypothetical character. But be it recollected, that to conceive and construct an hypothesis, by which unexplained phenomena may be accounted for in accordance with the analogies of nature, is always the first step towards discovery; and even though, from some oversight, it may turn out upon examination to be erroneous, the attempt to refute it sometimes reveals the truth.

END OF THE METEOROLOGICAL TREATISE.

A SUMMARY

OF THE

MORE IMPORTANT INFORMATION,

COLLECTED FROM VARIOUS SOURCES, RELATIVE

TO

MARSH FEVERS;

WITH

OBSERVATIONS ON THE VARIOUS MEASURES RECOMMENDED FOR THE PREVENTION OF THIS CLASS OF EPIDEMICS.

ON MARSH FEVERS.

Prefatory Observations.—Chemical science has hitherto afforded no information regarding the nature of infectious effluvia. Neither the tainted atmosphere of a fever-hospital, nor of a city infected with the plague where hundreds are dying daily, nor the noxious air from putrid marshes, nor that which is contained in apartments where persons have died of infectious diseases, has ever yet been found by chemical analysis, to contain any substance deleterious to human life, and to the presence of which the phenomenon of infection might be referred. Experiments with a view to such discoveries, and particularly to ascertain the nature of marsh miasma, have been often made, but uniformly without success. "M. Julia, who has paid considerable attention to chemical analysis, has sixty times subjected to trial the air of the marshes of Cercle, near Narbonne; of the pond of Pudre, near Sigean; of Salces and Salanque, in Roussillon; of Capestang, not far from Beziers; and of the different marshes on the coast of Cette;" and has constantly obtained the like results, which differed in no respects from the ordinary ingredients of atmospheric air. Various opinions, I am aware, have, on

this subject, been promulgated. By some, marsh miasmata have been supposed to consist of azote; by others of carbonic acid gas; some say hydrogen; others carburetted hydrogen; and others sulphuretted hydrogen. From such discordant opinions, it may with reason be inferred, that nothing hitherto has been discovered relative to this point, except that chemical analysis is as yet too imperfect to determine the composition of marsh miasmata, (and, it may be added, of other infectious effluvia,) or even to detect their presence. The fact, however, which demonstrates that the above conclusions are erroneous, is, that all those substances of which miasmata are said to consist, have often been evolved by artificial means in the laboratory of the chemist, without, in any one instance, producing disease.

The sense of smell is equally at fault in discovering the nature, or the presence of infectious effluvia. Certain marshes are observed to emit offensive odours; but others, where no such smells can be perceived, are known to be equally productive of the same species of fever. And in seaports, in the very focus where the yellow fever, the most deadly of all this class of diseases, has made its irruption, the olfactory nerves give to man no intimation of danger. Hence it may be concluded, that odoriferous particles are different from those which originate marsh fevers. In like manner, the presence of the various kinds of effluvia which communicate small-pox, measles, hooping-cough, scarlet fever, &c. to a healthy person introduced into the presence of the sick, cannot be discovered by the sense of smell. And it is said that

expurgators at Lazarettoes, have been known to be suddenly seized with the plague upon opening bales of goods from infected places, when no other evidence of the presence of the deadly instrument of communication could be detected. Finally, I have heard it stated that some practitioners could recognise the smell peculiar to the fever-ward of an hospital, and likewise that of an apartment where a patient labouring under Asiatic cholera was lying. But even in these cases, it is doubtful whether that which is perceived be the odour of morbid perspiratory secretions, or of the peculiar effluvia which generate typhus and cholera.

From these observations it is obvious, that all the knowledge we possess regarding the origin of epidemics, and of the mode in which they are propagated, and of the means by which they may be prevented, or avoided, is founded upon inferences deduced from observing the localities, the coincidences, and other circumstances in which they make their appearance, contrasted with those in which immunity from their influence is maintained. And in order to connect and explain these, as well as all the other phenomena which the history of such diseases reveal, we are forced to believe in the existence of material instruments of communication susceptible of atmospheric diffusion, to which the names of effluvia and miasmata have been assigned; but of the nature or composition of which, it is probable that mankind are for ever destined to remain ignorant.

Epidemic diseases may be divided into three classes:—

1*st*. Those which originate exclusively in endemic causes, such as a miasma engendered by the soil operated upon by heat and moisture, or some peculiarity in the water, or in the manner of living of the mass of the people. Marsh fevers may be given as an example of the former, and the Goitres of Switzerland as an example of the latter.

2*d*. Those which arise from atmospheric causes, such as great, sudden, and sometimes frequently repeated transitions from heat to cold, or from dryness to dampness, or the opposite. To this class belong cattarh and influenza; and likewise coughs and all slight inflammatory diseases arising from catching cold.

3*d*. Those whose origin is unknown, but which are kept alive, and propagated from man to man, by means of infectious effluvia generated during disease. To this class belong small-pox, measles, scarlet fever, typhus fever, plague, Asiatic cholera, &c.

The first of the above classes, viz. marsh fevers, goitres, &c. exhibit the distinguishing characteristics of non-contagion, viz. restriction to the localities which give them birth, and making their appearance simultaneously in all places similarly circumstanced with regard to soil, heat, and moisture, or other local causes; however distant from each other, or however secluded from human intercourse.

The second class, viz. catarrh and influenza, &c. also exhibit peculiar attributes, which are likewise indicative of non-contagion. They may be distinguished from the first class, by not being restricted to certain localities; and from the third class, from the following

circumstances. 1*st*, From their never spreading and travelling progressively from town to town, and from district to district, with the slow progress of pilgrims, vagrants, armies, or caravans. 2*d*, From their respecting neither non-intercourse, nor frequent intercourse. 3*d*, From their showing no preference either for thickly or for thinly peopled districts, nor for the usual tracks of commercial intercourse, such as highways, navigable rivers, and canals. 4*th*, From their indiscriminately and simultaneously invading all places and countries, however distant or secluded from each other, where those sudden or successive atmospheric vicissitudes which produce them, have occurred.

The third class, viz. small-pox, typhus fever, plague, Asiatic cholera, &c. differ from the two preceding classes, by presenting the strongly marked, and never to be mistaken features of infection; the chief of which are the following:—1*st*, Attacking successively those, or more frequently a portion only of those, who, by proximity of dwelling, and communication with the diseased, are most exposed to infection; such as the different members of the same family, and inhabitants of the same tenement, particularly those who attend the sick, or frequently enter, and perhaps sleep in the apartment in which they lie. 2*d*, Spreading from one house to another according as their inmates have visited, or have had communication with persons from infected dwellings, or have received body clothes, or bedding, previously used by infected persons. 3*d*, Spreading from town to town, and breaking out upon, or immediately subsequent to, the arrival of ships, troops, or individuals, from in-

fected places; those usually being the first attacked who had recently visited the seat of infection, and there imbibed the poison. *4th*, Travelling progressively from one country to another, (like the Asiatic cholera, without regard to the direction or velocity of the wind,) along the leading thoroughfares of commerce, whether by sea or land, and whether by highways, navigable rivers, or canals: following the march of armies; and making their irruption not simultaneously in distant localities similarly circumstanced, but consecutively, so that their path, interspersed with occasional leaps over an intermediate village, can be traced on a map, and the successive dates of their appearance at each town and village on their way, may be chronologically recorded.

It is only of the first of these classes of epidemics that we mean now to treat, and in doing so, we will confine ourselves exclusively to marsh fevers, partly in consequence of the great mortality resulting from them, which, according to Bancroft, exceeds that of all diseases incident to mankind;* and partly because the facts concerning them, and the laws that regulate their appearance and disappearance, are most interesting, and best established. Without farther preface, we will proceed to give

A SUMMARY OF THE MORE IMPORTANT INFORMATION, COLLECTED FROM VARIOUS SOURCES, RELATIVE TO MARSH FEVERS; WITH OBSERVATIONS ON THE VARIOUS MEASURES RECOMMENDED FOR THE PREVENTION OF THIS CLASS OF EPIDEMICS.

* See Bancroft's Essay on Yellow Fever, p. 490.

It has long been observed, that the insalubrity of warm climates, bears a general relation to the marshiness of the soil, and to the degree of heat to which that soil is exposed. All level low-lying countries, such as are frequently found on the banks, and near the mouths of rivers; and particularly those which are liable to be inundated during rainy weather, and afterwards, from want of a sufficient declivity, retain a swampy character, are, when much subjected to solar heat, the most productive of disease. Mr Annesley, in his work on the prevalent diseases of India, and of warm climates generally, refers the different sources of miasma, or malaria, to the following heads:—1*st*, Marsh lands, and the low grounds along the banks, and at the mouths of rivers; 2*d*, The low, dense, luxuriant copsewood, called Jungles in the East; 3*d*, Forests, situated in valleys; 4*th*, Rice-grounds; 5*th*, Canals and ditches, pools, and lagoons. To these we may add clay soils, and such as are rich with vegetative nutriment, particularly if allowed to lie fallow, or to remain uncultivated and unploughed. Wharves likewise, particularly when composed of rich alluvial depositions, and constructed so as to encroach upon the bed of a river, seem, when under the influence of a vertical sun, to yield miasmata possessing the strongest morbific powers.*

The diseases which such localities generate, are chiefly of the febrile kind, varying in degrees of ma-

* Peat-bogs or moors do not appear to generate marsh miasmata, nor their attendant class of diseases. This is supposed to be owing to their antiseptic quality, enabling them to retard the decomposition of vegetable and animal substances.

lignity from the fever and ague or intermittent, to the deadly yellow fever. In Batavia in the island of Java, vegetative life presents itself in its greatest luxuriance and variety; " but the atmosphere is continually infected with deleterious vapours which rise from the surrounding swamps and morasses; and the trees with which the quays and streets are crowded, impede the free circulation of the air, and retain the putrid effluvia, which otherwise would in some degree be dissipated. Here fevers are continually raging, and of strangers who come to settle, three out of five are reckoned to die the first year." The Pontine marshes in Italy near Rome, are proverbially productive of miasmata which occasion fevers; and I have been told that in many parts of the United States of America, particularly near the banks of the Ohio; and in many other districts where a large proportion of the lands possess a swampy character, autumnal sickness is every year so general, that it may be said in some degree, less or more, to affect the whole population.

Indeed, in all warm climates without exception, wherever morasses and pools of stagnant water exist, or wherever inundations of rivers leave vegetable or animal substances to putrefy in moist muddy soils, exposed to the burning heat of a vertical sun, fevers, sickness, and unhealthiness of climate, are never-failing attendants. But the fact which most satisfactorily proves such soils operated upon by heat to be the cause of disease, is, that no sooner are the marshes, and the pools of stagnant water impregnated with vegetable and animal substances removed, than the fevers and sickness ascribed to them in a great mea-

sure disappear, and the climate becomes more salubrious. Calcutta, which is situated in the midst of a flat and marshy country, was, at its first establishment as a European colony, almost as destructive to human life by reason of the insalubrity of its atmosphere, as Batavia. By clearing away part of the trees and jungle, and by draining some of the most offensive marshes in the neighbourhood of the city, and filling up many of the tanks in the streets, the climate, though still very trying and dangerous to the constitution, particularly of new-comers, is said to have become much less so than it was. In the United States of America it is observed, that gradually as the lands are getting drained, cleared of woods, and cultivated, so in proportion are the agues and autumnal fevers becoming less frequent, and less virulent. And in the county of Essex in England, and also in Cambridgeshire, Lincolnshire, and the East Riding of Yorkshire, agues and intermittent fevers, which were formerly very prevalent, have become, since the soil has been better drained and cultivated, comparatively rare.

"Violent fevers," says Dr Bancroft, "which were considered as pestilential, formerly prevailed very often in the summer and autumn at Bourdeaux, and frequently compelled the parliament to remove to other places. The Cardinal de Sourdis, having formed a just opinion of the cause of these fevers, undertook to drain a very offensive marsh, which then existed on the west of the city. Accordingly, two great canals were dug by his orders, and at his expense, to convey the stagnant water into the river, and a fine causeway being erected over the infected spot, and

planted with rows of elm trees, the plague, so called, ceased to appear."

That heat is an auxiliary in the formation of morbific marsh miasmata, is proved by innumerable facts. In cold latitudes where the greatest summer heat is inconsiderable, the inhabitants of swampy soils are but little disturbed with marsh fevers. In climates where the difference between the summer and winter temperature is considerable, marsh fevers seldom or never make their appearance till the heat of summer begins to be oppressive. At first they are not only less frequent, but their symptoms are in general comparatively mild; but it is observed, that as the heat of summer advances, and particularly in those years when the heat becomes unusually great, the fevers increase not only in frequency, but also in virulence and malignity of character. Gradually, however, as the temperature declines, marsh fevers again become not only less frequent, but milder and less dangerous, till at length, upon the accession of frost or cold weather, they entirely disappear.

The corresponding seasons of different years vary extremely in their productiveness of marsh fevers. In general much rain in the end of spring, and during the first half of summer, followed by excessive heat and drought, give rise to the greatest prevalence, and the most malignant kinds of marsh fever. In such seasons the yellow fever becomes epidemic in many places, chiefly seaports, where in ordinary years it is unknown.

To the preceding rule there are exceptions, which depend upon differences in respect to the dryness of

the soil of different places. In order to promote the putrefaction of vegetable substances, moisture, and air, as well as heat, are required. "Accordingly," says Bancroft, "it is found, on the west coast of Africa, and in some of the West Indian islands, which are liable to long droughts, as Barbadoes, and more particularly Antigua, that marsh fevers occur very seldom in those dry seasons; but that they become very prevalent whenever these droughts are suddenly terminated by frequent rains." On the other hand superfluity of moisture, such as results during inundations, retards the putrefaction of vegetables, and the disengagement of miasmata, principally, it is supposed, by secluding them from the action of the air. Accordingly it is observed, that the vapours arising from marshes are innoxious, until so much of the water has been evaporated, as to expose the surface of the soil to the atmosphere. And in like manner, in certain low tropical countries, such as the Dutch and French colonies on the coast of Guiana, viz, Surinam, Berbice, Demerara, and Essequibo, as well as at Cayenne, and the adjoining settlements, the inhabitants are most healthy during the rainy season when the lands are overflown; and fevers are rarely seen among them, until the prevalence of dry weather has so far caused the water to evaporate, as to leave the surface of the ground uncovered in many places. In such countries, fevers only prevail in the latter part of the dry seasons.

In places where, from declivity, draining, or other causes, the soil, when exposed to solar influence, soon becomes exhausted of moisture, great heat accom-

panied with occasional showers is most favourable to the production of miasma and fever. In short, it is when the soil is exposed to the action of the sun and air, and in the state of mud, or rather perhaps between that state and absolute dryness, that deleterious miasmata are most copiously exhaled. And in different localities, all the variations observable relative to the season of the year, and to different years, when marsh fevers become most prevalent and malignant, are regulated by the different degrees of heat and moisture, requisite to bring the soil to the most favourable state for the exhalation of miasma.

The period of the year when marsh fevers become most prevalent, is usually sometime after the annual atmospheric temperature has passed its maximum. The number who died daily of the malignant yellow fever at Barcelona in 1821, increased till about the middle of October, but after that period, the fever rapidly subsided. In the seaports of the United States, the yellow fever never makes its appearance, till after the temperature in the shade has remained for several days at or above 80 degrees of Fahrenheit; and at such times, a thermometer sheltered from currents of air, and exposed, like the ground, to the sun, would stand between 130 and 160 degrees.

That inundations of rivers when succeeded by heat are causes of malaria, is proved by many facts. Macculloch tells us that in Egypt the season of fever commences with the subsidence of the Nile. At Bassorah the same effects, and to a highly destructive degree, are produced after the overflowings of the Euphrates. At Rome, immediately after an inunda-

tion of the Tiber in 1695, they were visited with a destructive fever. And similar fevers arise in various places on the banks of the Don, the Danube, and the Rhone, when inundations of these rivers are succeeded by heat. Inundations of salt water occasioned by high tides are, in Mr Annesley's opinion, no less productive of miasmata in intertropical climates, than those which arise from fresh water floods.

It has been supposed that a moist heated air is sufficient of itself to occasion marsh fevers, without the aid of any undetected materials being diffused throughout the atmosphere, which they call miasmata. This supposition however is disproved by many facts. Marsh fevers never originate at sea in warm climates, even during the rainy season when the air is damp to saturation, unless the ships have previously touched at unhealthy places where such diseases prevail, and where the poison is imbibed which subsequently gives rise to morbid coporeal action. Neither do marsh fevers make their appearance on shore in warm climates during the rainy season, except in the vicinity of marshes and other suspicious soils. And no sooner are the marshes drained, though the heat and moisture of the atmosphere during the rainy season remain as great as ever, than the fevers cease to appear.

Another fact of importance connected with marsh fevers, and which seems to be completely established, is that persons become less liable to be affected by them, and if affected, the symptoms are usually less severe, and less dangerous, according to the length of time that they have been exposed to the influence of warm climates, and particularly to such as are most

productive of marsh miasmata. It is accordingly universally admitted, that persons who go from a cold to a warm climate, are much more liable to be affected by fever, and that too with more malignant symptoms, during the first year of their residence, than ever afterwards. In the seaports of the United States of America, when the autumnal fevers appear, it has been observed, that strangers and new-comers, particularly those who have recently left a cold climate, are the first to be attacked; and while the natives, and the strangers whose constitutions have been long seasoned to the influence of warm and marshy countries, are merely affected with mild intermittent and remittent fevers, the same disease attacks new-comers from cold latitudes, with all the malignant symptoms of the deadly yellow fever.

In the 60th number of the Quarterly Review, I find it stated, that "the countrymen who come down in the harvest time into the Campagna, Modena, Ferrara, Bresse, &c. where the rice-grounds and marshy districts are principally situated, are most frequently attacked with the fever, even when the season was considered favourable by the natives. A similar observation was made at Walcheren; it was also remarked that strangers were variously affected according to the district whence they came. Thus it was found that those of the British troops who were natives of mountainous countries, and dry soils, were more frequently affected than the natives of flat and moist districts. General Monnet, who commanded the French troops in Flushing during the whole of the seven years it was in their possession, recom-

mended that they should not be frequently changed; for when it was the custom to send battalions from Bergen-op-Zoom every fourth night, in succession to work on the lines of Flushing, these men never failed, on their return to be taken ill in great numbers. General Monnet, therefore, advised that a stationary garrison should be retained in Walcheren, in order that it might be habituated to the air; and he adduced an instance of a French regiment which suffered only one half the sickness and mortality in the second year of its being there, which it experienced during the first half-year, and it scarcely suffered at all in the third."

In conformity with the same analogy, it is noticed, that those whose constitutions from birth, or long residence, have become habituated to the influence of warm and marshy climates, are less liable to be affected by marsh fevers upon removing to a colder latitude, than the natives of the country to which they have emigrated. Thus, in the West Indies, and also in the United States of America, it has been observed that negroes recently imported from the warmer climate of Africa, and even their descendants, are less liable to suffer from marsh fevers, than the natives of America, or of the West Indies.

But though it is completely established that persons become less liable to be affected by marsh fevers, and if affected, that the symptoms are usually less severe, and less dangerous, according as their constitutions have become more habituated to marsh effluvia by long residence in warm swampy climates, still the reason why it is so, is not understood. From various

analogies, I am disposed to think, that this, as well as several phenomena presented by infectious epidemics, principally depend upon an unexplained property peculiar to the nervous system, of being more susceptible of impressions, and of exciting proportionally stronger corporeal action, according as it has been less habituated to such, or similar impressions; and *vice versa*, of being less susceptible of impressions, and these consequently only capable of exciting proportionally feebler corporeal action, according as it has been more habituated to such, or similar impressions. Thus, a person of weak constitution can be brought by the long use of opium, to stand a dose, without experiencing any great inconvenience, which would destroy several strong men unaccustomed to it. Again, upon entering an apartment impregnated with candle smoke, or any other odour, our sense of smell immediately communicates the fact; but after remaining a short time exposed to its influence, we become altogether unconscious of its presence. It appears also that the less accustomed the olfactory nerve has previously been to any odour, the more sensitive it is to its impression; and *vice versa*. Thus, I have been informed by a friend, upon whose veracity I can depend, that in Gottingen in Sweden, where wood only is used as fuel, that a person newly arrived from England can be detected by the smell of coal emanating from his clothes, and which must have been deposited upon them when in this country. Now, in this island where coal is generally used as fuel, and where our sense of smell must be frequently exposed to its influence, we are totally unconscious of its odour. Upon

analogous principles I conceive, that a small portion of marsh miasma imbibed by a person newly arrived from a cold latitude, and who has previously been altogether unaccustomed to such an emanation, will produce a much stronger influence upon his nervous system, and through its agency, may be expected to produce more virulent morbid action in his corporeal frame, than upon a person whose nerves have long, or frequently, been exposed to similar impressions.

Upon similar principles, infectious epidemics, (that is, diseases which are communicable from man to man through the instrumentality of some unperceived effluvium emanating from the lungs, or skin, or other discharges of patients, labouring under them,) are most infectious, and most deadly, upon their first breaking out; and this is particularly the case after a long disappearance of the same disease. On the other hand, all infectious epidemics become milder in their symptoms, less deadly, and seemingly less infectious, according as they are of more frequent occurrence, and according as they continue for a longer time in the same place. Thus, in that malignant and infectious species of Asiatic cholera which originated in India in 1817, and in the course of seventeen years travelled over the greater part of the earth, it was observed, that the number of deaths relative to recoveries were similar, and always much greater at its first appearance in every town or district which it visited; and that the proportion of deaths gradually became less, the longer the disease continued in any place, until it entirely disappeared. It might be supposed that these effects should be as-

cribed, partly to the increasing care to avoid infection, after the disease had shown its deadly nature; and partly to the circumstance of the most susceptible persons, and whose constitutions might also be the least capable of withstanding the disease, being apt to be the first infected. But every person who witnessed the epidemic, and saw the number of miserable drunken objects who escaped infection, and the little care taken to avoid infection upon the decline of the epidemic, must come to the conclusion, that the above results were principally owing to the circumstance of the nervous systems of those exposed to the infectious effluvium, having become in some degree habituated to it, and on this account less liable to be excited to morbid action thereby. Analogous facts support this conclusion. For instance, it is observed that nurses, and medical attendants, upon their first introduction to the fever wards of an hospital, are exceedingly liable to be infected with fever. But if they exercise caution in exposing themselves to the infectious effluvium emanating from the patients' lungs, and skin, for some time after their first introduction to the hospital, their nervous systems become by habit so insensible to its influence, that no morbid corporeal action can be thereby thereafter excited; and they are consequently seldom or never subsequently attacked with the disease. Were it not for this providential arrangement, it would be almost impossible to procure persons to attend upon those who had the misfortune to be attacked with any infectious epidemic.

The progressive travelling propensity of infectious epidemics, and their incapacity to return over the

same ground which they have previously traversed, except in a very limited degree, can only be explained upon the same principle. After remaining in one place for a short time, the nerves of the persons most exposed to the noxious effluvium become so insensible to its influence, that it ceases to communicate disease ; or if disease be communicated in rare instances, it usually appears in a milder form, and it is seldom propagated farther. Thus, it was observed, that the Black Death which traversed the earth in the 13th century; and the infectious cholera in the present century, (and the same remark is probably more or less applicable to all infectious diseases,) became gradually milder after remaining in any place for a short time; and that they travelled onwards from one town, and from one country to another, and seldom or never returned, (except in a very limited degree,) to any place which they had previously visited.

Farther, it is by no means improbable, that habit exerts different degrees of influence in diminishing the deleterious consequences of different kinds of infectious effluvia, according as they are more or less akin to such as mankind are constantly, or frequently exposed. This may be the reason why certain epidemics present a more general, and more permanent infectious character than others; and why they remain longer in the same locality.

The non-liability of persons to be infected a second time, (except in extremely rare instances,) with such diseases, as small-pox, measles, and scarlet fever, &c.; and the reason why a second attack of such infectious distempers, as the plague, Asiatic cholera, &c., is

usually observed to be less virulent than the first, probably depends upon the same principle, viz., a gradually increasing insensibility of the nervous system to be acted upon by any exciting cause, according as it has been more exposed to its influence. The optic nerve presents phenomena somewhat analogous. By continued exposure for a short time to a very strong light, this nerve becomes insensible to the influence of light, and incurable blindness is the consequence. Such a misfortune has sometimes befallen persons with naturally weak eyes, who persisted in viewing a partial eclipse of the sun for a considerable time, without the protection of a smoked glass. Inferior, and less permanent degrees of insensibility to light, are experienced by too long exposure to strong light. And every person must have observed, that, in passing from the light of day into a darkened room, (meaning thereby an apartment into which very little light is admitted,) it takes some time before the eyes become so sensitive to a small quantity of light, as to make surrounding objects visible.

Finally, it is not improbable that the gradual recovery of a patient labouring under an infectious disease, (and possibly of many other diseases not infectious,) depends upon the same peculiar property of the nervous system, viz., that of becoming gradually insensible to the exciting cause of disease, and consequently less capable of prolonging the morbid corporeal action, according as it becomes more habituated to it. Without the aid of some such hypothesis, it is difficult to comprehend how a person should recover from an infectious distemper, exposed as he

must always be to an effluvium emanating from his own person so deleterious in its nature, as to be capable of communicating a like disease to a healthy person, introduced for a short time into the same apartment. If this hypothesis regarding the manner in which many diseases work their own cure be correct, all violent remedies which in any degree weaken the patient, are to be suspected of doing harm instead of good. By unnecessarily reducing the strength of the patient, his body is rendered less capable of withstanding the virulence of the disease, till such time as the growing insensibility of the nervous system to its exciting cause, performs the natural cure.

Upon this point we will only farther remark, that when a nerve has become insensible to any exciting cause by continued exposure to its influence, some change in its physical constitution must have taken place. But in what that change consists we are totally ignorant. We will now return from this digression to our subject.

No climate yet discovered is too hot for the existence of marsh fevers. Indeed it is generally admitted, that if other circumstances be equally favourable, the hotter the climate is, the more prevalent are fevers; and the more malignant their symptoms. To this conclusion it might be objected, that in latitudes considerably distant from the equator, such as those in which New York, Philadelphia, and Charleston lie, the autumnal fevers which attack the natives, frequently manifest a more malignant character, than they do in warmer intertropical climates. This effect, however, is to be ascribed to the circumstance of con-

tinued warmth, exerting a stronger influence than that which is temporary, in conferring power on the human constitution to resist the evils which heat occasions. The average annual temperature at Philadelphia is much lower than it is near the equator, but then the heat is less uniform. The summer is about as warm, while the winter is much colder, and accordingly, its inhabitants are comparatively only half seasoned to the influence of a warm climate.

The reason why the most malignant species of marsh fever, viz., yellow fever, is principally confined to towns, seems owing to a combination of causes:—1*st*, To the greater warmth in towns,—their temperature being usually 3 or 4 degrees higher than that of the surrounding country. 2*d*, To their inhabitants living more intemperately than those of the country. And 3*d*, To the greater number of residents unhabituated to the climate.

Though marsh fevers vary considerably in their symptoms in different seasons, and in different climates, and have received different appellations, they nevertheless seem to be essentially the same disease, varying only in degrees of malignity with the temperature of the climate, the quantity of miasma, the duration and constancy of exposure to its deleterious influence, and the different degrees of unsuitableness in the human constitution to resist the evils which miasmata create. The accuracy of this opinion rests not merely on the similarity of circumstances which originate all marsh fevers, and which increase or diminish their virulence, and terminate their existence, (for they all simultaneously cease upon the accession of frost and cold wea-

ther;) but also upon their making their appearance at the same time and place, and running into each other by insensible gradations. "Never," says Dr Rush of Philadelphia, "has the unity of our autumnal fever been more clearly demonstrated, than in our present epidemic. Its four principle grades, viz., the intermittent, the mild remittent, the inflammatory bilious fever, and the malignant yellow fever, have all run into each other in many instances."

Though it be now universally admitted, that marsh miasmata are material substances capable of communicating diseases to the human frame, yet from the mass of evidence adduced by Bancroft, and other writers, it appears to be completely established, that those diseases are not in themselves infectious. From their never appearing but in the same localities, and in such only where there is an obvious, or a suspected cause in the vicinity; and from their never spreading from those localities, nor being communicated onwards in a progressive manner to places at a distance, where there is no local cause for their appearance; it is reasonable to infer, that the human body, when labouring under such diseases, does not generate within itself, or at all events, does not propagate around a corresponding effluvium to that which produces the disease. And from the same facts it is reasonable farther to infer, that marsh effluvia either do not deposit themselves on clothing, or on articles of merchandise; or if they so deposit themselves, that they do not continue to retain their poisonous quality, so as to be transferable from one place to another in the

ordinary routine of human intercourse, or of mercantile transactions.

As the non-contagiousness of marsh fevers, and particularly of the yellow fever, has been repeatedly called in question, and as it is of most essential importance to ascertain the truth as to this point, not only in regard to the precautions necessary in attending the sick, and in separating them from the healthy; but also to determine the propriety of enforcing quarantine regulations relative to these diseases; it may not be amiss to introduce a very limited selection of evidence, in support of the opinion above advanced.

"What may be considered," says Dr John Hunter, "as an *experimentum crucis* to prove the non-existence of contagion, is, when the sick leave their usual residence, and go to other places which are healthy, without spreading the disease. This," he adds, "constantly happens in the remittent fevers of the West Indies," among which he includes the yellow fever.

"It seems highly probable," says Dr Bancroft, "that in many cases the miasmata producing yellow fever in seaport towns of the West Indies, and the United States of America, arise from the soil immediately around, and, perhaps, sometimes under, the very houses, wharves, &c. where they are imbibed by the persons in whom that fever afterwards appears. Accordingly we find that in New York, Philadelphia, Baltimore, Norfolk, and Charleston, this fever always begins, and often continues exclusively in the low streets immediately adjoining the harbours and wharves of these towns, except in the cases of some individ-

uals, who, after having imbibed the noxious exhalations of the wharves and low streets in question, by residence or employment in or near them, happen to fall sick in other situations." And in another passage he says: "One fact, which decidedly proves the yellow fever to be destitute of any contagious power, is that of its never having been communicated to others by any one of the many thousands, who, in the West Indies, as well as at Charleston, Norfolk, Baltimore, Philadelphia, New York, &c. were removed beyond the reach of marsh miasmata, whilst labouring under the disease, or after having imbibed its poison; though in many of these, the disease appeared in its worst forms, and proved mortal."

"The impossibility," says Bancroft in another passage, "of spreading the disease in situations remote from marsh miasmata has been attested, not merely by persons who believed it not to be contagious, but by one of the strongest assertors of the contrary opinion, by the very person who appears to have first misled Dr Rush, and others on this subject, (I mean Dr Lining of Charleston,) more than half a century ago. His words are these, "Although the infection was spread with celerity through the town, yet, if any from the country received it in town, and sickened on their return home, the infection spread no farther, not even so much as to one in the same house."

The manifesto of 15 physicians assembled at Barcelona respecting the cause of the deadly yellow fever of that city in 1821, presented to the Cortes, is equally satisfactory. Two of the conclusions to which they came after the most minute inquiry were: That

the disease was indigenous, and not contagious; and that the sanatary measures adopted by the government were precarious, wholly useless, and even prejudicial, if we except that of emigration. And one of the numerous facts as related by Dr M'Lean, upon which the preceding conclusions were founded, is, that "those who left Barcelonetta, with all their effects, without submitting to the purifications enjoined by the contagionists, did not carry the disease to any of the healthy points to which they were destined; and if a few of them sickened, the causes having been applied at Barcelonetta, none of their companions or attendants were affected, who had not anteriorly been in the focus of infection."

In Philadelphia the non-contagiousness of yellow fever is so firmly believed, that after the sick who are labouring under this disease have been removed from the seat of contagion, (which as a means of cure is a common practice,) it is not unusual for acquaintances to visit them without the slightest apprehension of danger, and it has never been known that any evil consequences therefrom resulted.

The most conclusive evidence however upon this subject, is to be found in the official reports, made to the constituted authorities of the various towns in the United States, where the yellow fever has appeared. Dr Miller, in his report to the governor of New York, says: "Many who had contracted the disease in New York, died of it at Boston, Albany, and other cities at a distance; many likewise at Greenwich, Brooklyn, and other villages, in the neighbourhood. In no instance did these victims of the

epidemic communicate contagion." And in another passage he says, " No communication of the disease was ever observed in yellow fever hospitals, situated at a small distance from the cities to which they belong. No exception to this has ever occurred in any of the numerous seasons of this pestilence at our hospital at Bellevue, the marine hospital at Staten island, that of Philadelphia, or any other in the United States; provided the malignant air of the city had been avoided." Without quoting other reports, it may be stated, that in every instance, after the fullest and most rigid investigation, the result has been to demonstrate in the most satisfactory manner, that the yellow fever, and other inferior degrees of marsh fever, are not communicable.*

Upon the preceding evidence we will only remark, that the incapacity of an epidemic to spread or travel from certain districts where it appears either constantly throughout the year, or periodically during a portion of the year, or only in certain favourable years, is the only infallible criterion of its being non-contagious. It is this species of evidence that has settled the question with regard to yellow fever. The broadly asserted fact, that those who have been affected with this malady when removed, according to common custom, to yellow fever hospitals, or to the houses of relatives at a distance from the source of the miasma, have never been known to communicate the disease to attendants who avoided visiting the infected district, extinguishes all other kinds of opposing evi-

* For farther evidence we refer to Bancroft's essay on Yellow Fever.

dence. Such an assertion, unlike other facts relative to contagion, admits of no evasion or misrepresentation. It is open to the scrutiny, and if untrue, to the contradiction, not of individuals, but of thousands of individuals in New York, Philadelphia, and the other cities where the disease appears.

Another fact that seems to be completely established, and which it is of most essential importance should be known by all those who have occasion to visit countries where marsh fevers prevail, is, that the liability of being affected is much greater during night, than it is during day. "It is related," says Bancroft, "by Dr James Lind, that in a voyage to the coast of Guinea, performed in the year 1766, by the Phœnix ship of war, of 40 guns, the officers and ship's company were perfectly healthy, till, on their return home, they touched at the island of St Thomas. Here the captain unfortunately went on shore, to spend a few days in a house belonging to the Portuguese governor of that island. This happened during the rainy or sickly season. In the same house were lodged the captain's brother, the surgeon, some midshipmen, and the captain's servants. But, in a few days after their being on shore, the captain, his brother, the surgeon, and every one, to the number of seven, who had slept in that house, were taken ill; and all of them died except one, who returned to England in a very ill state of health. The ship lay at anchor there twenty-seven days, during which time three midshipmen, five men, and a boy, remained on shore, for twelve nights, to guard the water casks, under pretence that the islanders would steal them; all of whom were like-

wise taken ill, and two of them only escaped with life. At that island, only those who slept on shore were taken ill. And none of those who slept on shore escaped the sickness, and of them only three survived it."—The extract proceeds, but I only here insert the substance of it, viz. " That in another similar voyage the next year, the same vessel touched at the same island during the sickly season, where she lost eight men out of ten, who had imprudently remained all night on shore. The rest of the ship's company, who always returned to the ship before night, though they spent the greater part of the day on shore, continued in perfect health."

Dr Trotter, late physician to the royal navy, says: " In a voyage down the coast of Guinea, in the Assistance, in the year 1762, we had scarcely a man indisposed. We wooded and watered at the island of St Thomas, and with a view to expedition, a tent was erected on shore, in which the people employed on these services were lodged during the night. On the middle passage, every man who slept on shore died, and the rest of the ship's company remained remarkably healthy."

Dr John Clark relates, that a Danish ship in 1768 having anchored at North Island, near the straits of Sunda, twelve of the crew were sent on shore to fill water, where they only remained two nights. Every one of them were seized with a fever of which none recovered; but, although the ship went out to sea, none except the twelve who slept on shore were attacked with the complaint.

It may be remarked, that the preceding facts, as

well as many similar ones, which, for the sake of brevity, we omit, strongly corroborate the opinion that marsh fevers are not contagious. In each of the cases related, the portion of the ship's company who had not slept on shore communicated freely with those who had, both after, and immediately previous to their falling sick, and yet none of them were infected.

In farther proof of the danger to be apprehended from exposure to night air in marshy countries, I may mention, that it has long been observed in Rome, (and strangers are usually warned of the danger,) that those who, to avoid the heat of the day, travel, during the sickly season, through the Pontine marshes between Rome and Naples by night, though it only takes six or eight hours to pass through them, are exceedingly apt to be immediately thereafter affected with fever.

From the preceding and such like facts, some have imagined that it is the act of sleeping, and not of remaining exposed to night air, that is dangerous. It is possible that the relaxation of the system during sleep, may, to a limited extent, diminish the power of the body in resisting the noxious influence of miasma; but this alone will not explain the phenomena. It has repeatedly occurred that individuals who happened to stop late on shore, even though they did not sleep there, were soon after attacked with fever; while those who returned to their ship upon the approach of evening escaped. Nor is there any evidence, that those who avoided sleep while passing through the Pontine marshes by night, were less liable to be afterwards affected with fever, than those who slept. And in cor-

roboration of the same opinion, I have been told by persons who resided long in New York and Philadelphia, that it was in both these towns the general belief, founded upon common observation, that when the yellow fever was raging, little danger was to be apprehended by perambulating the streets of the infected district during the heat of the day, but great danger at night.

Though the risk incurred by visiting a marshy district be unquestionably much diminished during day, still it is not altogether annihilated. In Philadelphia and New York, cases of infection have been known to result from persons entering, and remaining for a short time in unventilated houses and stores in the sickly part of these towns, even during the hottest period of the day. And one of the last times the yellow fever broke out in Philadelphia, the persons first attacked were a few coopers employed during the day at a particular part of the wharf, where the poisonous miasma must have been issuing from the soil in a very concentrated form. The facts of this case were published in an official report, but I only learned the substance of it from a relative of my own who then resided at Philadelphia. As the facts here alluded to tend to show, that the danger arising from marsh miasma increases with the duration of exposure, and probably with the amount inhaled, it may not be amiss to state them. They are as follow :—" Part of the coopers had been employed in the dangerous spot the whole day, and one or more of them were there only part of the day, and the master had merely visited them, and that only for very short spaces of time, at

intervals during the day. Those who laboured there the whole day all died; those who had been there only a part of the day after a severe illness recovered; and the master of the workmen was only affected with nausea, vomiting, and the other incipient symptoms of the yellow fever for about two hours."

I have only met with one fact to corroborate the preceding opinion, and it does so only indirectly. It is a statement by Dr Bancroft, (page 384,) to the following effect, that "as the fever receded from the low ground, and malignant atmosphere of Water Street, it became more and more mild and manageable, till its evanescent shades in Second Street were in many instances, much lighter than the common remittent of the country." The inference I draw from this quotation is, that the miasma became more and more diluted with the atmosphere as the distance from the source of emanation increased; and that the malignity of the fever depended upon the amount of the poisonous miasma actually inhaled, without its making much difference whether the inhalation of it was continued for one hour in a more, or for several hours, in a proportionally less concentrated form.

From a variety of well authenticated facts, some of which we will quote, it appears that a few feet of perpendicular elevation has a remarkable influence in diminishing the danger arising from marsh miasmata.

It is related by Dr Hunter, that, in Spanish Town, in Jamaica, the difference in the healthiness of the ground-floor of the barracks, and of that immediately above it, was so great, that of a similar proportion of inmates, it was found, upon investigation, that three

of those who slept in the former were attacked with fever, for one who slept in the latter. A similar case occurred at St Anne's barracks in Barbadoes. It was there likewise ascertained, that about three in the lower floor took the yellow fever, for one in the floor immediately above it. The testimony of Dr Ferguson, one of the principal medical officers of the army in St Domingo in the late war, is to the same effect. He remarked, that two-thirds more men were taken ill on the ground-floors, than in the upper stories.

Dr James Clark relates the following instance communicated to him by Professor Brera, whilst attending the clinical wards of the hospital at Padua. The wall of that wing of the building where these wards are situated, is washed by a branch of the sluggish Brenta, and it frequently happened that the windows of them, (which were about sixteen feet above the surface of the water,) having been carelessly left open, until too late an hour, several of the patients were attacked with intermittent fevers, in some instances of the pernicious kind. This never occurred in the women's wards, which are immediately over those of the men, though there is no reason to believe that more care was taken in shutting the windows of those, than of the former. It was also remarked at Walcheren, that those who slept in the upper stories of houses were less liable to the disease, and had it in a milder form, than those who slept on the ground-floors. The testimony of the natives was likewise in favour of this observation.

The greatest height in the atmosphere to which marsh miasmata ascend, or rather the height at which

the quantity existing becomes so small as to be incapable of communicating disease, can hardly be said to be ascertained. It probably increases with the heat of the climate, and of the season of the year, and also with the stillness and density of the atmosphere, and the quantity of miasma generated, and the extent of its source underneath. "On this subject, the Baron de Humboldt has observed, that the farm of Encero, situated above Vera Cruz, is a stranger to the insalubrity which reigns over the whole coast; the elevation of this farm is 3045 feet, and it forms the highest limit of the yellow fever. M. Rigaud de l'Isle has also endeavoured, by some observations made in the neighbourhood of Rome, to fix the point at which the marsh effluvia are innoxious; this he considers to vary from 682 to 1006 feet above the level of the situation whence they emanate."

In order to account for a variety of the facts which we have related, it has been usually conceived, that marsh miasmata are specifically heavier than common air. Hence upon their assuming the gaseous form, though they tend like odours and other aeriform substances, and probably by means of the same unknown force, to diffuse themselves equally throughout the atmosphere, yet their greater specific gravity counteracting this tendency, not only prevents their rising above a limited altitude, but causes the greatest proportion to float near the surface of the ground, and restricts their greatest accumulations, and the increased danger thence arising chiefly to hollows and low-lying places.

The preceding hypothesis, so far as it goes, is

probably correct; but it requires additional assistance to explain all the phenomena. During day, as has been previously stated, little or no more danger is to be apprehended from miasmata in low, than in elevated situations; and upon the accession of frost and cold weather, whether during night or day, danger in all situations ceases. In explanation of the former of these facts, it can hardly be supposed that a greater amount of miasma is generated during night than during day. Indeed, there is a sufficiency of indirect evidence to prove that the reverse is the case. For instance, 1*st*, Marsh fevers are common to marshy districts in all hot climates, and if other circumstances be equally favourable, their frequency and malignity is proportional to the degree of warmth: on the contrary, in similar situations in very cold latitudes, such fevers are altogether unknown. 2*d*, In temperate climates, marsh fevers never make their appearance till the summer heat is considerable, and they are observed to increase in frequency and virulence as the temperature rises; and subsequently to become milder, and of less frequent occurrence, as the temperature declines, until they entirely disappear. 3*d*, In every instance where bodies are known to be capable of assuming the gaseous form, an increase of heat promotes their volatilization; whereas, an increase of cold not only retards it, but, if carried to a sufficient extent, prevents it altogether. These reasons induce me to think, that the amount of miasma volatilized in a given time, increases like the quantity of water evaporated, with the temperature of the source from whence it emanates; and consequently

must be greater during the heat of day, than it is during the chillness of night, and will increase as the temperature of the season advances, and diminish as it again declines.

In accounting for the greater liability of being affected with marsh fevers arising from the greater accumulation of miasmata during night than during day, the dissipating influence of the sun is usually referred to, without any explanation of the manner in which the effect is produced. We will, therefore, supply this deficiency, by pointing out the mode in which the solar heat must promote the intermixture and dilution of miasma with the atmosphere, for it is probably to this circumstance that the beneficial influence of the sun is to be ascribed.

During day, the surface of the ground, where it is exposed to the sun's rays, becomes warmer than the atmosphere; and this superior temperature being communicated to the stratum of air in immediate contact with it, diminishes its specific gravity, and causes it to ascend. Thus the sun, even during the stillest weather, by promoting the intermixture of the various atmospheric strata, is a constant source of ventilation; for agreeably to aerostatic principles, the warmer and lighter atmospheric particles underneath, must be continually ascending during day, while the colder and heavier particles from the upper strata of the atmosphere, must be simultaneously descending to supply their place. Besides, miasma generated during day, by partaking of the solar warmth which is then communicated to the surface of the ground, will be thereby rendered specifically lighter. Both

which circumstances co-operating with the diffusive tendency of miasma, will accelerate that intermixture and dilution of it with the atmosphere, which may reasonably be supposed to render it harmless, and incapable of communicating disease.

During night, particularly when there is little or no wind, and the sky is clear of clouds, the above circumstances, which promote ventilation, and the dissipation of miasma, are reversed. The surface of the ground, as has been proved by the observations of Dr Wells, then becomes colder than the lower atmospheric strata; and this coldness being communicated upwards, the temperature of the air during serene nights, has been found to increase to the height of 220 feet, and how much higher is unknown, as observations have not been extended farther. Hence, during night, the various atmospheric strata, unlike what takes place during day, become specifically heavier according to their proximity to the surface of the ground; and instead of tending to intermix with each other, are enabled, even in opposition to the agitating influence of any slow progressive motion over a slightly uneven surface, to retain their relative positions during the whole of the night. Besides, the specific quantity of whatever miasma is exhaled during night will be increased, by its partaking of the then superior coldness of the earth's surface. And this circumstance, which is the reverse of what happens during day, will co-operate with the greater specific gravity of miasma in counteracting its tendency to diffuse itself upwards through

the atmosphere, and consequently, will favour its accumulation near the ground during night.

Though the influence of the preceding circumstances go a considerable length towards accounting for the greater liability of being affected with marsh fevers during night, than during day, still, the explanations thereby afforded are not altogether satisfactory. If heat diminishes the specific gravity of miasma only to the same extent as it does that of air, it is difficult to conceive how the solar warmth should be able, in opposition to the greater gravity of miasma, to prevent all accumulation of it near the surface of the ground during day, so as effectually to destroy the liability of being then affected by fever; or why, upon the return of night, its accumulation near the surface of the ground should so quickly re-appear. Nor does it explain why, upon the sudden accession of frost and cold weather, the previously exhaled miasma should so suddenly disappear.

After reflecting upon these difficulties, and upon the various phenomena connected with this subject, I am inclined to think that to explain them satisfactorily, requires us to suppose, in addition to the explanatory circumstances already stated, that the specific heat of miasmata is greater than that of common air; and accordingly, that with equal increments and decrements of temperature, the specific gravity of the former, will decrease and increase more than that of the latter. By the aid of this supposition, the previously mentioned explanatory circumstances, which of themselves barely account for some of the phenomena, and for others not at all, become much more

efficient. Nor is this hypothesis by any means extravagant. For, in the first place, all the knowledge or ideas we possess regarding the existence, the habitudes, the movements, and the effects of miasms, are merely conjectural inferences, deduced in order to account (as this is intended to do,) for certain phenomena otherwise inexplicable. In the second place, all bodies, whether simple or compound, that have been examined, differ in their specific heat; and though there be a general tendency towards a relation between the specific gravity, and the specific heat of bodies, yet, the departures from this relation are so numerous, so irregular, and in many instances, so great, that to suppose an additional departure therefrom to account for phenomena, which in order to an explanation, point that way, is far from being an extravagant conjecture. The specific heat of miasms can only differ from that of air by being greater or less; and as we cannot ascertain which is greatest or least by direct observation and experiment, we are left to determine this point by considering which of the two suppositions harmonize best with the phenomena, and accordingly which will explain them most satisfactorily.

Agreeably to the hypothesis that the specific heat of miasma is greater than that of common air, the following effects ought to be produced.

1. As temperature rises, the difference between the specific gravity of miasma and air, (supposing the former to be the heaviest,) will diminish, and of course, will exert lest influence in counteracting the ascension of miasma, while acting in obedience to its

tendency to diffuse itself equally, (upwards as well as horizontally,) throughout the atmosphere. On the contrary, as temperature sinks, the difference between the specific gravity of miasma and air will increase; and of course, will exert a proportionally augmented influence in counteracting its tendency to diffuse itself upwards through the atmosphere.

2. As the temperature of the air rises, its capacity for containing miasma, whether it exist in a state of solution, or of mere suspension and mixture therewith, will increase, just upon the same principle as the capacity of the air for humidity, (which has also a greater specific heat than air,) increases with its temperature.

The conjoint operation of these two circumstances, satisfactorily explain the principal difficulties attending the phenomena of marsh miasmata. The increasing coldness as we rise above the earth's surface, operating upon the greater specific heat of miasmata, explains the reason, why the altitude to which they ascend is limited; and why at greater heights, marsh fevers are unknown. Though the temperature of miasms be reduced only in the same degree as the particles of air at a similar elevation, still, this reduction of temperature increases the specific gravity of the former, more than that of the latter: and hence, the tendency of miasms to diffuse themselves upwards, must obviously be at length counteracted by the increasing coldness, just as the ascension of aqueous vapour is counteracted, and limited, by the same cause.

The reason why marsh fevers do not appear in

winter, or in high latitudes; and why they cease in temperate climates, upon the accession of frost and cold weather, is evidently explicable upon the same principle as the phenomenon above explained. In consequence of the superior specific heat of miasms, the coldness in high latitudes, or during winter, will increase their specific gravity so much more than it does that of air, as to prevent their assuming the gaseous state, in which alone they are supposed capable of occasioning fevers. In like manner, in temperate latitudes, upon the accession of frost or cold weather, the farther volatilization of miasma will not only be prevented, but that which has been previously exhaled and diffused throughout the atmosphere, will be precipitated to the ground; and hence, the fevers which in the aeriform state they occasioned, must thereafter disappear.

The greater liability of being affected by marsh fevers during night than during day, likewise admits of a much more satisfactory explanation, by the assistance of the hypothesis above advanced, than it does without it. During the heat of day, the specific gravity of miasms and air being more nearly approximated than during the chilness of night, the same amount of exhaled miasma will rise not only to a greater altitude than it would otherwise do, but will diffuse itself more equally amongst the higher and lower atmospheric strata; and thus, by being diluted with the intermixture of a larger proportion of air, will become less dangerous. On the contrary, the coldness during night, by increasing the specific gravity of miasma more than that of air, will cause a

gradual precipitation of the former towards the earth's surface, upon the same principle, as aqueous vapour is precipitated in like circumstances in the form of mist. Hence, the miasma that ascended during the warmth of the previous day, by becoming specifically too heavy to float during night in the higher and rarer regions of the atmosphere, will descend; and instead of being equally diffused amidst the higher and lower regions of the air, will accumulate in greatest proportion amongst its inferior and denser strata; and thus increase the danger to be there apprehended.

The increasing virulence and frequency of marsh fevers as the summer heat advances, and their subsequent diminution in malignity and frequency as the temperature again declines, also harmonizes with what might be anticipated from the greater capacity of air for miasms as its temperature rises, an effect which must result, like in the analogous case of humidity, from the specific heat of miasms being greater than that of air. Owing to this circumstance, the amount of deleterious miasma capable of floating in a given bulk of air, and the danger to be thence apprehended, will increase as the summer heat advances, and decrease as it again declines. And upon the same principle, if other circumstances be equally favourable, the amount of miasma floating in the atmosphere, and the insalubrity of the climate thence arising, will be proportional to its warmth.

Thus we see that the various phenomena presented by marsh fevers, are in strict accordance with what might be expected to result from the specific heat of the miasma, which occasions them, being greater than

that of air; and that the difficulties attending their solution, by aid of this supposition disappear. The correctness of the hypothesis is farther confirmed by considering what would result from a contrary supposition, viz. the specific heat of miasms being less than that of air. In this case, miasms would diffuse themselves upwards through the atmosphere with greatest facility during the chilness of night, and again descend and accumulate in greatest proportion amongst its inferior and denser strata, during the heat of day; and the amount capable of floating in the atmosphere, instead of increasing should diminish with the warmth of the climate, and of the season of the year. Hence, contrary to what is known from experience to be the fact, the liability of being affected with marsh fevers should be greater during day than during night; and should decrease as the warmth of the climate and of the season of the year advances. And were it not unnecessary to illustrate this point farther, it could in like manner be shown, that all the other phenomena which ought to result upon the supposition of the specific heat of miasma being less than that of air, would be directly the reverse of what are actually presented.

That marsh miasmata are susceptible of being transported by aerial currents, particularly when their velocity is moderate, so as to communicate disease at a distance from their source of exhalation, is completely ascertained. Dr Lind, speaking of the unfortunate attempt to make a settlement at the island of Balambangan, near Borneo, where scarcely one in ten of those sent thither survived the first six months, says:

"From October till April, during the north-east monsoon, the wind comes from the sea, and the settlement is perfectly healthy; but from April till October, during the south-west monsoon, the wind blows over the marshes, both of this island and Borneo, and produces fevers of the most malignant nature, which frequently cut off the stoutest men in 12 or 14 hours."

Regarding the distance from the source of emanation, to which marsh miasmata diffuse themselves horizontally in such abundance as to communicate disease, either in still weather, or by the aid of aerial currents, medical opinions vary extremely. Bancroft supposes the distance very limited, viz. not farther than from one-fourth to half a mile, even in the most favourable circumstances. Macculloch, on the other hand, conceives, that by means of aerial currents, they may travel hundreds of miles without much dilution with the atmosphere. He supposes, for instance, that easterly winds in spring give rise to agues in England, in consequence of their transporting the malaria of Holland thither; and a similar opinion is advanced by a writer in the Seventy-second number of the Edinburgh Review. Before hazarding an opinion upon this subject, we will quote a limited selection of facts:

"According to Sir Gilbert Blane, not only the crews of the ships in the road of Flushing were entirely free from the endemic of Walcheren, but also the guard-ships which were stationed in the narrow channel between Flushing and Beveland, the width of which is about 6000 feet; and although some of the ships lay much nearer to one shore than to the other, there was no instance of any of the men or

officers being taken ill with the same disorder, as that with which the troops on shore were affected; whilst ships at the distance of 3000 feet, and even farther from swampy shores in the West Indies, were affected by the noxious exhalations; and the same thing is said to occur in the India ships in the channel leading to Calcutta." It need hardly be stated, that the object of the writer of the preceding extract from the Quarterly Review, is to prove, that deleterious exhalations in general, possess more morbific and malignant qualities, in proportion to the warmth of the climate in which they are engendered. The argument itself, so far as regards the object of the writer, is entitled to little consideration. A more extended horizontal diffusion may obviously arise from the greater abundance of miasma; but stronger morbific properties appertaining thereto, is no more indicated by a greater, than it would be by a less diffusive tendency. We know that marsh fevers are more malignant and fatal in warm than they are in cold climates; but whether this be owing to stronger morbific properties in the miasmata, or to their greater abundance, or to the united influence of both these causes operating, in conjunction with the greater heat of the climate, upon the human constitution, it is impossible, in the present state of science, to determine. But to proceed with our statement of facts.

In Philadelphia, the yellow fever seldom or never spreads farther than the low part of the town, being chiefly restricted to Water-street, and others immediately contiguous to the wharves and banks of the river, where the miasms which occasion the disease

are supposed to be engendered. In New York the same thing has been observed. The seat of the fever is there likewise confined to a corresponding locality in the lower portion of the city; and the mere avoidance of that district during the sickly season, is said to afford perfect security against the disease.

It may likewise be briefly stated, without quoting the facts individually as related by medical authors, that it has been often observed with regard to fleets anchored on sickly coasts, that the crews of the vessels nearest the shore were affected with sickness, while those only a cable length or two farther off, remained perfectly free from disease. In such cases it has also been found, that the sickly ships upon removing a little farther from the shore, became healthy.

In the town of Kingston, in the island of Jamaica, the sickly season commences about the beginning of August, after the usual sea breeze from the east has died away, and continues till November, when the sea breeze again recovers its ascendancy. The sickness during this period is with good reason ascribed to the exhalations from marshes about five miles to the west of the town; for it is observed, that it is only when the land breeze blows from that direction, and it generally does so only very gently, that sickness prevails. It is also remarked, that the part of the town which is farthest removed from the marshes, is the healthiest. In this instance, it appears that marsh miasma, aided by an extremely gentle breeze, which is chiefly perceptible in the morning, communicates disease at

a distance of five miles from the source from whence it emanates.

From the case of Rome we cannot draw any satisfactory conclusion. No marshes exist within a dozen miles of that city; but it has been usually believed, that the soil of the surrounding country, and even the stagnant water, and filth within the city itself, engender deleterious miasms.

From the preceding facts and others of a similar kind related by medical authors, we may draw the following conclusions :—

1. In perfectly still weather, marsh miasma is most abundant above the source of exhalation; and the amount diffused horizontally gradually decreases, so that at the distance of little more than half a mile from its source, and frequently much nearer, it becomes so diluted with the atmosphere, as to be incapable of communicating disease.

2. When there is any wind, no danger is to be apprehended from miasmata, except to the leeward of their source of emanation: but in this direction, particularly during night, and when the breeze is very gentle, miasmata may be conveyed to a distance of five miles in such a concentrated state as to communicate disease.

It need hardly be remarked, that the inferred limits above stated, are merely approximations to the truth so far as has been determined by observation. It is obvious, however, that the distance to which miasma may diffuse itself horizontally during still weather; or to which it may be transported by means of aerial currents, in a sufficiently concentrated state

to communicate disease, will vary with circumstances; such as, the extent of the source of exhalation, and the amount exhaled in a given time; the elevation of the source of exhalation relative to that of the surrounding country; and the degree of obstruction, which trees, houses, rising grounds, or other inequalities of surface, present to its diffusion. In Philadelphia, New York, and other towns, the diffusion of miasma in such a concentrated state as to communicate disease, is limited by a combination of the above causes; such as, the smallness of the source of exhalation, and of course the smallness of the amount exhaled; the comparative lowness of the parts of these cities where it is engendered; and the interruption which the houses present to its spreading horizontally. The distance of diffusion will also vary with the weather. During day, provided the sun's rays are not obstructed by clouds, the miasmata will be rapidly dissipated, as has been already explained, even above the source of exhalation. But in cloudy weather, when the sun's rays are obstructed, and little heat is communicated to the earth's surface, and to the lower atmospheric strata, miasmata, without much dilution, may diffuse themselves horizontally, in still weather, or may be transported by the wind to a considerable distance even during day. During night, however, when the lower atmospheric strata become colder and specifically heavier according to their proximity to the surface of the ground, the distance of diffusion and transportation, and the danger thence arising, will be always greater than it is during day.

Macculloch's idea of miasmata being transported for hundreds of miles in such a concentrated state as to communicate disease, I regard as an extravagant conjecture unsupported by any thing like satisfactory evidence. If such were true, distance from marshes, contrary to what is known from experience to be the fact, would afford little or no protection from the danger thence arising. Even supposing, agreeably to Macculloch's notion, that the same identical portion of air is transported for hundreds of miles without intermixture with other portions, (which, judging from the obvious effect of unevenness on the surface of the ground in producing intermixture, is extremely improbable,) still the diffusive tendency of miasma itself, must be continually operating in promoting dilution during its progress. Besides, the circumstance of the deleterious influence of miasma being so extremely circumscribed in the hottest climates, as it appears to be from some of the facts we have stated, leads me to think, that in addition to the effect of coldness in precipitating miasmata from the atmosphere, there must be some extensive chemical agency constantly at work in decomposing them, totally incompatible with their distant transportation in any concentrated, or dangerous form. We know that all excess of carbonic acid gas formed during combustion and respiration, beyond the proportion natural to the atmosphere; and that all odoriferous particles, as well as all known gaseous substances engendered during the decomposition of vegetable and animal matter, are soon precipitated by means of some unknown chemical agency; and that they never are transported by

aerial currents beyond a very limited distance. Hence, judging from analogy, it is presumable, that miasmata assume the aerial form only for a limited time; and thereafter return to the earth to undergo that peculiar succession of changes, which in the course of their chemical revolution they are destined to perform.

Strong winds or hurricanes are said to diminish the danger arising from marsh miasmata, not only during their continuance, but even, as is believed, for some time thereafter. The island of Bourbon is usually visited by one or two hurricanes in the course of each year. They happen between the months of December and March, which, as the island is in the southern hemisphere, corresponds to the sickly period, in warm climates, in the northern hemisphere, between July and October. The salubrity of this island is ascribed in a great measure to these periodic storms; for it is observed by the inhabitants, that the want of them is invariably succeeded by unwholesome seasons.

The influence of strong winds and hurricanes in diminishing the danger arising from marsh miasmata during their continuance, is obviously owing to the copious dilution of these, and all other noxious vapours with the atmosphere, which they occasion. In proportion to the rapidity with which the air passes over the exhaling marshes, so must the amount of miasma, which it thence receives, be smaller. And even this diminished amount, will undergo more copious dilution, according as an increased velocity of the aerial current over the uneven surface of the ground, has a stronger influence in promoting the in-

termixture of the higher and lower atmospheric strata. The efficacy of hurricanes in promoting healthiness for some time thereafter, probably results from their sweeping away, not only all deleterious miasmata that may have been previously exhaled, but also by means of the force with which they impinge upon the exhaling surfaces, all that is about to assume the aerial form.

Another fact of importance is the influence of a screen, whether it be a forest, a stone wall, or any other intercepting body, in sheltering places to leeward from the pernicious effects of marsh miasmata. The following facts will illustrate this point.

In Rome, one side of a street is said to be sickly, in consequence of being exposed to the external miasmata brought thither by the wind, or by its own diffusive tendency; while the opposite side of the same street, by means of the shelter it receives from the first line of buildings, is comparatively healthy. I have also been informed by a medical gentleman who resided for some time in Rome, that the part of the city where the Jews principally reside, which is the lowest lying, the closest built, and in every respect the worst ventilated district, is notwithstanding the healthiest during the sickly season: and the reason assigned, is the shelter from the external miasma which this district receives from the intervening buildings.

In one of the West India islands, I forget which, the inmates of a barracks were very liable to be affected with fevers when the wind blew from a certain direction, in which lay swampy lands. As a measure of

prevention, the windows that looked towards the marshes were built up, and the unhealthiness of the barracks was thereafter in a great measure removed.

M. Rigaud de l'Isle relates that near Saint Stephano, on Mount Argentel, in the midst of an unhealthy country, a convent is situated which was famed for the salubrity of its air, so long as it was surrounded with woods, but since the cutting of these it has become unhealthy. At Velletri near the Pontine marshes, the cutting of an intermediate wood occasioned, immediately and for three successive years, fevers and other diseases, which committed great ravages: the same effect was observed to result from a similar cause, near Campo Salino; and also in many other places.

In explanation of the preceding facts it may be remarked, that the benefit arising from such apparently inadequate means of protection, is principally to be ascribed to the great specific gravity of miasmata. Hence their tendency to attach themselves to solid bodies, such as trees, that they meet with in their progress; and hence likewise, the proximity to the ground at which they float, and their consequent inability to surmount any perpendicular obstacle, such as a stone wall, at the only time they are concentrated and dangerous, viz., during night.

Regarding the channel through which marsh miasma make its injurious impression on the animal frame, nothing has been ascertained. Mr Annesley thinks, (and his opinion is probably correct,) that it acts chiefly through the medium of the air passages of the lungs; but whether the material cause is absorbed,

or operates on the nervous system only, he does not attempt to determine, though he thinks it probable that it may operate in both modes.

In conformity with what is known of many other absorbed poisons, a certain time elapses, which varies in different constitutions, between the period of inhaling the deleterious miasma, and the appearance of disease. This fact has been completely demonstrated in those cases, (one or two of which we formerly quoted,) in which vessels having touched at unhealthy islands, those of the crew who slept on shore, and them only, were all subsequently, and successively at different intervals after exposure to infection, attacked with fever. In general, the most malignant fevers make their appearance soonest after infection. In malignant cases, the interval between infection and the appearance of disease, may vary from 10 hours to a fortnight; but in intermittents, and mild remittents, though they likewise may appear soon after infection, it has been supposed, that the poisonous miasma which occasions them, particularly if imbibed upon the approach of cold weather, may lurk in the body for several months, and at length develop itself in the form of disease. Bancroft (p. 241.), after quoting several remarkable facts in proof of this latter circumstance related by Dr John Hunter, says: "Extraordinary as these facts appeared to be when first made known, the fullest confirmation of them has been since produced by the late expedition to Zealand; in which it has been indisputably ascertained, that considerable numbers, both of officers and soldiers, who were employed on that service, and who

escaped the sickness, whilst at Walcheren, and other parts of Zealand, were attacked with intermitting fevers, and some of them as late as six, seven, eight, and even nine months, after being brought back to this country; though care was taken to place them generally in situations remote from all the known sources of marsh miasmata.

The proportion of mankind who die of marsh fevers, and of other diseases arising from marsh miasma, though much diminished in later times in consequence of better draining, is still very great. Macculloch states, (though the estimate is probably far beyond the truth,) that it has been rudely computed, that more than half the natural mortality of the human race is owing to marsh fever and its consequences. Nor is this great mortality the only evil arising from marsh miasma. According to medical authors, the inhabitants of districts most exposed to its influence, present an unhealthy and unhappy appearance. Even the powers of the mind seem to be thereby impaired. "It is an observation," says Macculloch, "as old as physic itself, that inferiority of the intellectual faculties is the inheritance of those who reside in marshy countries, and in a dense, foggy atmosphere."

Yellow fever, according to Bancroft, seldom destroys life in less than three or four days; but generally, though it may terminate fatally, this does not happen till between the 7th and the 15th day. In some of the most virulent kinds of this fever, however, death ensues within 24 hours of the time of attack. Dr Lind, as formerly stated, relates, that in the island

of Balambangan, in the East Indies, the fevers are so malignant as to kill the stoutest men in twelve or fourteen hours.

Of those who are seized with yellow fever, not above one-half, on an average, recover; and unlike what happens in the case of small-pox, measles, &c. the same individual may be attacked many times in the course of a lifetime. The persons most liable to this malady are males of a muscular and plethoric habit of body, between the age of 15 and 30, and particularly those who have recently arrived from a colder latitude. The aged, and the valetudinary, according to Bancroft, are not so apt to be attacked, as the vigorous, and the robust. Women are said to be less liable than men, and children less than either.

Treatment of Patients.—With a view to curing yellow fever, and all inferior degrees of marsh fever, the most important rule to be observed, and which, with slight modification, is susceptible of an extended application to all diseases arising from an infected atmosphere, is to remove the patient as soon as possible from the seat of contagion. The fatigue unavoidable in doing so, instead of being hurtful, even when the patient is reduced to a state of great weakness, is thought so beneficial, that Dr Jackson recommends the motion of a carriage as a means of cure. It is reasonable to conceive *a priori*, that to allow a patient to remain exposed to the influence of the miasma which originated his illness, and which is capable of communicating a similar disease to a healthy person, is neither the most favourable locality for effecting a cure, nor that in which he is likely to

receive the most suitable attendance. This point, however, has been set at rest, and the truth of what might have been anticipated confirmed, by the benefit observed to result from the practice of removal. In New York and Philadelphia, it has been ascertained, that of those who are removed to hospitals, or to the houses of relatives at a distance from the seat of infection, a greater proportion recover, than of those who remain where the disease was contracted. And even when death ensues after removal, the disease is observed, on an average, to take a longer period to destroy life.

Regarding the proper mode of curing the more malignant species of marsh fever, commonly called yellow fever, the opinions of different physicians, so far as medicine is concerned, are at antipodes. According to the writer of the article on Medicine in Brewster's Encyclopædia, some practitioners in the same situation, and during the same epidemic, carry the depleting system to an unheard-of length, while others ply stimulants and tonics with no less eagerness and confidence. Upon such opposite extremes in medical practice, it need hardly be remarked, that instead of being both right, they ought to be suspected of being both wrong; and by way of getting at the truth, it might be well to inquire, not which system does most good, but which does least harm.

The cold affusion repeated again and again during the progress of the disease, preceded by copious bleeding, and followed by blistering, injections, purgatives, and warm fomentations, (as if the cure depended upon the number and strength of the reme-

dies,) is recommended by Dr M'Lean. It is needless to inquire whether or not such rough treatment ever performed miraculous cures, for in the history of medicine, evidence of that kind is seldom wanting; but judging from the circumstance of its never having become general, as well as *a priori*, from its greater likelihood to injure a man in health, than recover one in disease, its propriety is more than questionable.

> Patients are to Doctors subjects,
> Fit for experiments and projects;
> Which though ailing by the bye,
> They seldom on themselves do try.
> 'Tis hence a leech proves better far,
> Than fifty armed men of war;
> For he by lance and purging skill,
> Can more than sword by hundreds kill.
>
> HUDIBRAS.

I am inclined to think, that in diseases where death or recovery soon ensues, violent and unnatural remedies are frequently believed to cure, for no better reason, than that they do not invariably kill. A considerable proportion of those attacked with yellow fever recover; and it is ever difficult to determine, whether this result be in consequence, or in spite of medical treatment. In all dangerous and rapid diseases where no certain remedy has been discovered, nor any uniform mode of treatment adopted, the safest practice undoubtedly is, to do little or nothing more than sooth the feelings, calm the fears, and gratify the taste and desires of the sick. And in yellow fever, all perhaps that should be done, beyond removal

from the seat of contagion, is to regulate the amount of covering agreeably to the patient's sensation of heat and cold; to minister to his excessive thirst and longing for fresh air; and trust the rest to the cautious, well-timed, and ever salutary efforts of nature.

In the cure of the less virulent kinds of marsh fever, viz. intermittents, and mild remittents, the invariable recommendation by medical authors of Peruvian bark administered during the intermission and remission of disease, and even during a state of convalescence, is satisfactory evidence of its propriety and utility. It is likewise an undisputed observation, that when the general health of a patient, originally from a cold latitude, continues long impaired after a fever, recovery is best perfected by returning to his native climate.

Preventive Measures.—Though marsh fevers be now happily almost unknown in Great Britain, they still prevail in our East and West India settlements. And if we reflect on the numbers of our fellow-countrymen, and even of our friends and relatives, that have occasion, in the pursuits of merchandise or of pleasure, to visit these or other countries where such diseases prevail; and whose lives are so often sacrificed to their ignorance of the means of preserving them, which such facts as we have quoted in the previous pages reveal, the importance of the subject, independent of the collateral information which it communicates, relative to the means of guarding against all pestilential diseases, appears. We will, therefore, before taking leave of our subject, briefly state, though in some cases it be partly to recapitulate, the means

found useful in destroying the deleterious properties of malaria soils; and the personal precautions necessary in order to avoid their baneful influence. Of these preventive measures, some, as will obviously appear, cannot be accomplished without the aid of public funds, and legislative enactment; while others are within the power of every one to adopt for himself. The former are properly objects that demand the interference of lócal and municipal governments; the latter require merely the exercise of individual prudence. Of the former class, the first we will mention is embankment.

The swampy character of a large proportion of the low-lying alluvial formations contiguous to the banks of rivers, and along the sea-coast, is partly, and sometimes wholly, produced by inundations during rainy weather, or high tides, to which they are periodically subject. Wherever this is the case, embankment is usually recommended as an obvious and efficient corrective of the pernicious qualities of the soil. The efficacy of this remedy, however, as we will subsequently have occasion to show, is more apparent in its immediate, than in its ultimate tendency; and its propriety can be better determined by the observation of local circumstances, than by general speculation.

When the swampy character of the soil is owing to its power of retaining moisture, whether received in the form of rain, or during inundations, draining, where the level admits of it, is the proper remedy. This corrective is with propriety in most cases left to private speculation, for it fortunately happens, that draining is the best means of fitting swampy soils for

purposes of husbandry; and the proprietor who thereby consults his own interest, simultaneously promotes the health of the community. The almost total disappearance of intermittents from our bills of mortality, is in a great measure to be ascribed to better draining, executed wholly for individual benefit, and at private expense. In the United States of America, a progressive tendency towards a similar result is likewise observed to keep pace with the increase of population, the consequent rise in the value of land, and its more extensive cultivation.*

The benefit of draining is not confined to the country: it is equally beneficial in towns. Its object being nothing more than to dry the soil, its efficacy is greatly assisted by paving and sweeping the streets. By these auxiliary means, all filth and stagnant water are not only removed; but the rain which falls, instead of soaking into the ground, is conveyed immediately into the common sewers.

In those towns where yellow fever frequently makes its appearance, and where the source from whence the miasma which occasions the disease emanates, is, as

* It need hardly be remarked, that the drainage of swamps should never be attempted during the sickly season; for such would not only be certain death to the labourers employed, but by reducing the swamps to the state of drying mud, (in which condition they are most productive of dangerous exhalations,) the sickness would in the first instance be thereby increased. The most fitting time for such operations is the middle of the day, and the coldest period of the year. Those employed should be natives, or long residents, who have become accustomed to the climate: they should likewise be well clothed and fed; and never worked so long as to feel exhausted or fatigued.

frequently happens, very limited, it is proper, in addition to the corrective measures above stated, to examine the nature of the soil, with a view to the removal of that part of it at least, which is nearest the surface, provided its character be suspicious. Soils are in general to be suspected of possessing deleterious qualities in proportion to their vegetative fertility, and their power of retaining moisture. Of course, in making a change, the rule to be observed, is to substitute that which is less fertile, and has a less retentive power in respect of water, for that which has greater fertility, and has a greater retentive power. According to Kirwan, soils that abound in the argillaceous principle, (that is, clay soils, or those in which clay predominates,) are the most retentive; and those that abound in the coarse silicious principle, (that is, sandy and gravelly soils,) the least; and calcareous or chalky soils are intermediate between the two. By the experiments of Bergman it appears, that argill takes up 2·5 times its weight of water when saturated so as to let none drop.

Magnesia,	1·05
Chalk,	0·5
Silicious Sand,	0·25

By this statement it appears, that Silicious Sand, which by itself is perfectly barren, has only $\frac{1}{10}$th part of the retentive power in respect of water that argill has. And hence the propriety of substituting sand or gravel for clay, and for loams in which clay predominates. This recommendation is so far in conformity with the observations of Linnæus. That great

naturalist observed, that intermittent fevers were most prevalent in clay soils: and Bancroft thinks that this is owing to their power in retaining moisture.

The preceding observations, so far as regards the nature of the soil, point out the safest situations for the encampment of armies in warm unhealthy climates; also for the building of hospitals, as well as private residences. And where the nature of the soil and other circumstances are equal, the more elevated the situation the better.

When, owing to the lowness of the land, the draining of swamps is impracticable, the most obvious remedy is to fill them up. In towns likewise the filling up of hollows, and the maintenance of proper levels with a view to draining, and dryness in general, is of essential importance to the health of their inhabitants.

The submerging of swamps where draining is impossible, has been also recommended. Moisture is in all cases necessary to vegetation; and different vegetable productions require soils that are very different from each other in this particular; but complete submersion seems about equally destructive to vegetation with the total absence of moisture. Soils subjected to solar influence are usually supposed to be most productive of miasmata, when in the state of mud, or between that state and dryness. Hence, drainage of swamps, which, in the first instance, would reduce them to this state, is particularly to be avoided during the warm and sickly season. And hence the propriety of submersion, when the heat of the sun during this period has a tendency to reduce them to this state. The efficacy of submersion in

preventing the exhalation of miasmata, is conceived by Beecher, to be owing to the great quantity of fluid opposing the decomposition of animal and vegetable substances.

Another recommendation is to prevent the stagnation of water in marshes, by directing the course of rivers through them. " Empedocles is said to have delivered the Salentini from the dangerous exhalations to which they were subjected, by conducting into their marshes two neighbouring rivers, which cleared them of their stagnant water ; and the air being no longer tainted, the diseases to which they had been previously liable ceased."

This subject acquires additional importance by contemplating the property, common in a greater or less degree to all rivers, of raising the level of their beds while traversing flat countries in their approach to the ocean. The cause of this property of rivers is obvious. The earthy materials with which their waters become impregnated during the higher and more rapid parts of their course, and particularly during inundations, are deposited as their basins expand, and their currents diminish in rapidity. Upon this point, by way of authority, we will insert a short extract from Baron Cuvier's Theory of the Earth.

" M. de Prony," says Cuvier,* " having been directed by government to investigate the remedies that might be applied to the devastations occasioned by the floods of the Po, ascertained that this river, since the period when it was shut in by dikes, has so greatly raised the level of its bottom, that the surface of its

* Page 128.

waters is now higher than the roofs of the houses in Ferrara. At the same time, its alluvial depositions have advanced so rapidly into the sea, that, by comparing old charts with the present state, the shore is found to have gained more than six thousand fathoms since 1604, giving an average of a hundred and fifty, or a hundred and eighty, and in some places two hundred feet yearly. The Adige and the Po, are at the present day higher than the whole tract of land that lies between them; and it is only by opening new channels for them in the low grounds, which they have formerly deposited, that the disasters which they now threaten may be averted.

"The same causes have produced the same effects along the branches of the Rhine and the Meuse; and thus the richest districts of Holland, have continually the frightful view of their rivers, held up by embankments, at a height of from twenty to thirty feet above the level of the land."

From the preceding facts and others of a similar kind, considered in conjunction with the circumstance of all such hollow intermediate lands, as those above alluded to, being unhealthy; the propriety in certain cases of opening new channels for rivers through low-lying marshy districts, only determinable by local survey, becomes apparent. Rivers are the great drains into which all minor ones empty themselves; and by which the superfluous water beyond what is necessary for vegetation, is returned to its parent ocean. But when the surface of the water in those great drains becomes higher than that of the adjoining country, drainage of the soil becomes impossible, except by

such expensive and inefficient methods, as digging reservoirs, and lifting the waters they receive over river embankments by means of marsh-mills, and other mechanical contrivances.

Besides, there is reason to think, that the marshiness of many districts, is partly owing to the greater elevation of the surface of the embanked rivers which traverse them. Springs issuing from the ground are ever owing to the absorption of water at a higher level, and which is sometimes conveyed by subterraneous channels to great distances from its source of introduction, before appearing at the surface. In like manner, wherever the elevated beds of rivers are in any degree permeable to moisture, portions of water may be expected to find its way by subterranean channels, so as to appear at the surface, and occasion marshiness of soil, at considerable distances from its source of introduction.

Such considerations show that the utility of embanking rivers is very questionable, unless the deepening process can be made to counteract their tendency to raise the level of their beds. Unembanked rivers uniformly direct their course along the lowest level, and thereby act not only as natural drains, but, if requisite, afford the greatest facility for additional artificial draining. Besides, the subsequent advantages resulting from inundations, unless they happen when crops are on the ground, in general more than compensate for their temporary inconvenience. While their alluvial depositions leave everywhere a fertile soil, they gradually fill up hollows, and raise the level of low-lying plains, so as eventually to prepare the

land for being permanently freed from that marshiness, and unhealthiness, which they at first promoted. By embankments these advantages are not only lost, but evils in a national point of view result. Gradually as the beds of embanked rivers are raised by successive depositions above the level of the surrounding country, drainage of the soil becomes not only more necessary, and more difficult; but the lives and property of a people so protected from inundation, are ever at the mercy of an enemy.

Another preventive measure is by legal enactment to discourage or prohibit, within a limited distance of towns, the cultivation of articles, such as rice, and the preparation of others, such as steeping hemp and flax, which are generally admitted to be productive of malaria. This might be considered an invasion of the right of private property; but it ought to be recollected, that the application of property to purposes injurious to health, deteriorates the property of others. Of two evils the least ought to be preferred. Health and household property are certainly objects as worthy of legal protection, as the value of land. Perhaps in agricultural districts, where there are few houses, prohibitions of this kind are inexpedient; but in the neighbourhood of towns, where the advantage increases with the amount of property, and the number of those whose health is to be protected, the propriety of prohibiting any mode of cultivation, preparation, or deposition of articles injurious to health, is unquestionable.

A counterpart to the preceding recommendation is by premiums, if necessary, to encourage within a

limited distance (say a couple of miles,) of towns, the cultivation of such articles, as correct the pernicious qualities of the soil. To this class sugar-cane, and such other vegetable productions as require much nourishment, are thought to belong. This opinion is founded upon Dr Jackson's theory of the source of miasmata. He conceives, that these deleterious emanations chiefly consist of the excess of vegetative nutriment afforded by the soil, beyond what the plants covering its surface can make use of in the way of growth ; and hence the reason that marsh fevers are most prevalent and virulent in warm climates; and in soils, and seasons, most productive of luxuriant vegetation. This theory I may observe is by no means established ; but it is nevertheless so much in unison with the leading phenomena attending marsh fevers, as to warrant the adoption of the above recommendation as a measure of precaution.

It has been uniformly observed, that constant cultivation and cropping of the land, and extracting from it as much produce as possible, has a powerful tendency in correcting its deleterious properties. On the contrary, allowing it to lie fallow, or to remain uncultivated or unploughed, has an opposite effect. With a view therefore to promote the salubrity of warm climates, particularly in the neighbourhood of towns, these observations are worthy of attention.

In towns where the source of the miasma which occasions disease is external, building a high wall, or planting a belting of trees in the intermediate space, may obviously, from facts previously mentioned, be serviceable. But wherever the source of disease is

within a town, widening, paving, draining, and sweeping the streets, and building them in straight lines ; and in general by removing every obstruction to the free circulation of air, such as trees and ramparts ; and by police regulations prohibiting and removing depots of filth, and decomposing vegetable and animal materials, also stagnant water, mud, and rich soil on or near the surface of the ground, particularly from wharves, banks of rivers, and low-lying places, are the most advisable preventive remedies.

Most of the precautionary measures within the power of individuals to adopt for themselves, and which we are now to enumerate, are obvious inferences from the facts previously quoted. Persons who wish to preserve health in warm sickly climates, particularly those recently arrived from cold latitudes, should avoid the night air, never venturing out of their houses during the sickly season for an hour or two after sunrise, nor remaining out after sunset. Elevated situations, as far distant as convenient from wharves, and marshy low-lying districts, especially those visited by sickness in previous years, should be selected for dwellings, and places of business. Sitting and sleeping apartments should never be on the ground flat, but as high above it as possible ; and the windows should never be opened from sunset till an hour or two after sunrise, and not at all when the wind blows from the marshy district.* In general, when the wind blows

* The recommendation given in the text, to keep the window shut at night during the sickly season in warm, swampy climates, is not applicable to the climate of Britain, nor to that of countries where marsh fevers are unknown. Mankind spend nearly one-

over marshes, exposure to it ought to be avoided, particularly during night, and for an hour or two after sunrise; and also during day, provided the weather be cloudy, or foggy. When exposure to night air,

third of their lives in bed. And as breathing fresh air essentially contributes to promote health and strength, the air of bed-rooms is particularly worthy of attention.

I made a lengthened series of thermometric observations conducted during all seasons of the year, partly to ascertain how far the air within a bed-room 12 feet square, with a northern exposure, underwent vicissitudes of temperature corresponding to those of the external atmosphere, the upper part of the window being open, by day and night, nearly two inches during winter, and about four inches during summer. The door of the apartment was kept open during day, but shut during night. The results of the observations, so far as applicable to the point under consideration, were as follow:—

1. The diurnal range of temperature within the bed-room was greatly less than that of the external atmosphere. When the diurnal range of temperature exhibited by a thermometer suspended outside of the window, was, on very rare occasions, as much as from 15 to 20 degrees, the range exhibited by a thermometer suspended inside of the bed-room, did not exceed five or six degrees. And when the diurnal range of temperature exhibited by the external thermometer, was about the mean, viz. from 7 to 8 degrees, the range of temperature, inside of the bed-room, did not exceed 2 degrees, and seldom was so much.

2. From my time of going to bed to that of rising, (the former varying, perhaps, from midnight to two o'clock in the morning, and the latter from 7 to 9 o'clock, A.M.) the thermometer inside of the bed-room varied, on rare occasions, as much as two degrees; more frequently it did not vary above one degree; and more frequently still it did not vary so much as one degree. And these variations almost always consisted of an augmentation of temperature, which I ascribed partly to the influence of the heat evolved by a person in warming a room; for the thermometer, outside of

or to winds blowing over marshes is unavoidable, the shorter the duration of exposure, the safer.

It is said that gauze frames fitted to the windows of houses much exposed to malaria, will arrest its progress; and likewise that sleeping under a mosquito net, in an infected place, will protect a person from the noxious influence of the atmosphere. These points have not been satisfactorily established; but when the efficacy of trees in robbing a current of air of its deleterious vapours is considered, it seems by no means improbable, that a gauze frame may have the effect above ascribed to it; and likewise that a mosquito net, or even that a muslin or silk handkerchief

the window, varied from one to eight degrees in the same time; and the variations were as often downwards as upwards.

3. The temperature in the bed-room was always considerably higher during night than that of the external atmosphere. Hence no injury can result during night from the intrusion of damp air; for however damp the external air may be, it becomes comparatively dry, hygrometrically speaking, upon entering the bed-room, in consequence of the augmentation of temperature which it then undergoes.

Now, as catching cold principally results from sudden and great variations of temperature, I infer from the preceding facts, that there is no risk of catching cold from sleeping with the bed-room window open one inch during winter, and two or three inches during summer, or perhaps considerably more. And from the air within the bed-room being thereby kept fresh and wholesome, and all respiratory and perspiratory vapours and gases allowed more freely to escape, I also infer that great benefit results not only to those in health, but also, and in a more especial manner, to the sick and the valetudinary from this practice. To insure perfect safety, it may be advisable, when the wind blows directly in at the window, or when the bed-stead is near the window, that a bed-curtain intervene between the window and the person in bed.

thrown over the face when asleep, may intercept the miasma during respiration, though it does not obstruct the passage of air. It is said likewise that the inhabitants of infected districts, are rendered less liable to the influence of malaria by being clothed in wool, living well, and keeping their houses warm and dry; and also, that when travellers are obliged to pass the night in malaria districts, the danger they run is much diminished, by keeping the air of their sleeping and sitting apartments dry and warm by means of a fire, so as to assimilate their corporeal warmth, and the temperature and hygrometric dryness of the atmospere by which they are immediately surrounded during night, to what they are during day.

Those who visit malaria districts merely on excursions of pleasure, and who usually can select their own time, ought to avoid doing so during the sickly season, viz., summer and autumn. And those who go to reside permanently in such climates, ought to study if possible to arrive there soon after the sickly season has ceased, in order that they may be somewhat habituated to the climate before it returns ; recollecting, that the danger is much greater, and precautions proportionally more necessary, the first year of residence, than the second ; and more the second, than the third.

When the yellow fever breaks out in a town, no precautions will afford complete security, except emigration to a healthy spot during its continuance. And as the sickly season is of short duration, and the seat of disease, particularly in towns, is usually so extremely circumscribed, that ten minutes' walk will

transport a person from the place of greatest danger, to one of perfect safety, it is folly to neglect such a simple and efficient means of prevention.

Ships of war, in touching at unhealthy climates during the sickly season, should lie at anchor as far as convenient from the land, particularly when the wind blows from that direction; and none of the crew ought ever to be permitted to sleep on shore, or remain there after sunset. When the wind blows from the land, especially during foggy or cloudy weather, and also during night or early in the morning, those of the crew who are not required on deck, ought to avoid exposure to the breeze, by going below.

Those who reside in malaria districts, should be particularly careful to avoid excessive fatigue, or long fasting, during the sickly season. Dr John Hunter observes, that if persons are exposed to the exhalations of marshes, when fatigued by hard labour and long fasting, the poison gains admission more readily into the body, and produces immediately the worst kind of fever. It is in this way, (he adds,) that soldiers suffer so much in actual service in the West Indies: the few cases of fever which proved fatal in twenty-four hours, that came under his inspection, were all contracted in that manner. Indeed, there is reason to believe, that every thing which reduces the vigour of the constitution, such as intemperance, debauchery, and irregularity in living; or obstructs the perspiration, such as damp feet, and exposure to cold, or rain, particularly after being much heated, either by exercise, or the sun's rays, has a similar effect with hard labour and long fasting, in rendering the body more liable to

be affected by marsh miasma. And, judging from the rapidity with which yellow fever, and other inferior degrees of marsh fever, have been observed to follow intemperance, fatigue, exposure to cold, and wet, &c. there are grounds for believing, that though a portion of the poison be introduced into the system, it may frequently be overcome, and got quit of, by the strength of the constitution, without producing disease; but if in such circumstances the body be exposed to any debilitating cause whatever, disease, which might otherwise have been averted, may be immediately brought on. Hence, with regard to regimen, it may be laid down as a general rule, that the avoidance of whatever reduces the vigour of the constitution either permanently or temporarily; and the adherence to that mode of living, which each person has found best calculated to promote his own individual health and strength, are, during the sickly season, and when exposure to marsh emanations, and other infectious effluvia, is unavoidable, the most likely means of preventing marsh fevers, as well as all other diseases.

Bleeding, laxative medicines, and spare diet, have been recommended to new-comers from cold latitudes, by way of assimilating their constitutions to that of natives, and of those who by long residence have become habituated to the climate. I very much doubt the propriety of the former part of this recommendation. We know little or nothing regarding those alterations in the constitution produced by long residence, which render the body less liable to the diseases of warm climates. The visible changes, (and

it is probable that those that are invisible correspond with them,) are an increased sallowness or darkness in the complexion, (supposed to arise from an augmented secretion of bile,) an enlargement in the caliber of the external blood-vessels; and a diminution in the amount of muscular fibre, and of fat. But bleeding and laxative medicines, I should suppose, instead of accelerating, will rather retard these; and possibly whatever other changes are effected in the constitution by long residence in a warm climate. Besides, by reducing the vigour of the constitution, they would probably have much the same effect as hard labour, long fasting, exposure to cold after being heated, or sudden exhaustion arising from any cause, in affording more easy admission to the poisonous miasma.

The latter part of the recommendation, viz. spare diet, being less artificial, and more in accordance with the dictates of nature, seems to be less objectionable. Judging from the circumstance of the muscular and robust being most liable to yellow fever, under-eating is probably less dangerous than over-eating; and a cooling diet preferable to one that is heating. These in reality are only Nature's prescription, and she, in all cases of uncertainty, is the safest physician. Appetite prescribes to a person newly arrived from a cold climate, the essentials of a spare and cooling diet, viz., an increase in the amount of liquid, and a diminution in that of solid food ; and so far, and no farther, spare diet may be recommended.

Dr Chisholme recommends the wearing of flannel next the skin in warm climates, with a view to keep-

ing the body in an equable degree of warmth. And when the security thereby afforded against all vicissitudes of temperature is considered; and particularly the supposed effect of the sudden transition from the heat of the day to the coolness of night, in rendering the body more apt to imbibe the poison, the recommendation is probably judicious. Upon this point, however, it may be remarked, that the sensations of heat and cold seem to have been given with a view to teach us instinctively to protect our corporeal frame from injury, arising from extreme, or unwholesome temperatures. And it is now universally admitted, that the temperature which is most agreeable, is also the most wholesome, not only to those in health, but likewise to patients labouring under any disease whatever. Now, as the atmosphere in warm climates is more frequently felt disagreeably warm than disagreeably cold, especially by new-comers from colder latitudes, it is reasonable to think, that if flannel is worn at all, it ought to be of the thinnest kind; and the outer garments ought on the same account to be also thin and cool.

Finally, It has been ascertained that substances, according as their colour is whiter, and their surface smoother, are better reflectors of heat; and when temperature is on the increase, absorb in a given time a smaller proportion of it, and consequently, in such circumstances, are the slowest in becoming warm; while on the other hand, they are proportionally worse radiators of heat, and accordingly, are the slowest of becoming cold when temperature is on the decrease. Hence, the lighter the colour, and the

smoother the outer surface of the external garments, the more eligible they are in all climates for preserving the body in an equable degree of warmth, both during the diurnal and the annual variations of temperature; and whether circumstances require exposure to the heat of the sun, or afford the protecting influence of the shade.

END OF THE ESSAY ON MARSH FEVERS.

AN EXPOSITION

OF THE

ERRONEOUS NATURE OF MR OWEN'S PLAN

FOR

AMELIORATING THE CONDITION OF MANKIND,

ACCOMPANIED WITH

OBSERVATIONS ON THE MEASURES AND POLICY CALCULATED TO PROMOTE THAT DESIRABLE OBJECT.

AN EXPOSITION OF THE ERRONEOUS NATURE OF MR OWEN'S PLAN FOR AMELIORATING THE CONDITION OF MANKIND, ACCOMPANIED WITH OBSERVATIONS ON THE MEASURES AND POLICY CALCULATED TO PROMOTE THAT DESIRABLE OBJECT.

To ameliorate the condition of our fellow-men, or in other words, to increase their happiness and diminish their misery, as far as lies in our power, is the duty of every member of society. The proposer of a plan which has only this object in view, is certainly entitled to a hearing, if not to our gratitude, for his philanthropy. But when its adoption requires great, and immediate sacrifices of comfort, and important alterations in our habits, and manner of living; it is not to be expected, unless he can clearly prove, that it would immediately, or ultimately, be attended with great advantage, that mankind will make any change. And if he persists in recommending it, after it has been often, and clearly demonstrated, that its adoption is impracticable; and if practicable, would be attended with injury instead of benefit to society, he has no claim to expect that mankind will regard him in any better light, than as an enthusiastic, well-meaning, but strangely infatuated visionary.

In the following paper, I purpose to commence with a summary of Mr Owen's plan, a knowledge of

which I have principally obtained from his own report on the subject to the county gentlemen of Lanarkshire. I will then examine the various items of which it consists; and endeavour to prove, that, separately considered, they are calculated to injure, and not to benefit society. And will conclude by showing, that, in its remote consequences, the universal adoption of his plan would ultimately spread, and greatly increase ignorance, poverty, and crime, instead of producing (as Mr Owen tells us) "incomprehensible knowledge, and incalculable wealth, even until it became so abundant that any farther increase to it, would be considered useless, and not to be desired." It may be likewise here premised, that, when treating of the last department of our subject, we will take the opportunity of reviewing a variety of the measures which have been proposed for ameliorating the condition of mankind; and will endeavour to discriminate between those that are, and those that are not, calculated to further this desirable object.

First, then, for the summary of Mr Owen's plan.

Mr Owen proposes to erect buildings in the form of parallelograms, which he says is the best form, capable of containing each, from 300 individuals as a minimum, to 2000 as a maximum; but from 800 to 1200 he considers the most desirable number for forming into agricultural villages. These buildings are to be erected as near as possible to the centre of the land belonging to them; and are to contain the sleeping, dining, and cooking apartments of the villagers; as well as the store-rooms, and granaries for holding their redundant wealth. Also an inn for the

accommodation of travellers ; an infirmary for the diseased ; and in the centre of the parallelogram, a church and two schools ; one for the education of infants from two to six, and the other, for children from six to twelve years of age. The workshops for carrying on the manufactures of the different necessary, and ornamental articles for the use of the villagers, are to be placed at some distance from the parallelograms, under a plantation. Each parallelogram is to have attached or belonging to it, from 150 to 3000 acres of arable land ; but generally from 800 to 1500 acres, that is, from half an acre, to an acre and a half, for each individual, less or more in proportion as it is reckoned most advisable, to hoard up their redundant, or unconsumed wealth, in manufactured goods, or in agricultural produce. And each association, generally speaking, is to create for itself, a full supply of the necessaries, conveniences, and comforts of life.

The education of the young is not to be conducted through the medium of books, but systematically by means of sensible signs ; and all is to be produced by the knowledge of some new science, which he absurdly supposes he has discovered ; and which he calls, a knowledge of the science of the influence of circumstances over human nature. The present mode of promoting education by exciting emulation from hope of reward or dread of punishment, he says is not only productive of all the bad, but destructive of all the good qualities in human nature. In his system of education therefore, these are to be superseded by a knowledge of the science of the influence of circumstances over mankind.

The villagers, to save the trouble of separate cooking establishments, are to take their meals all together at the same time and place. And their dress is to be loose, and similar to that of the Romans, or Highlanders.

One of the first measures which Mr Owen proposes, in order to let prosperity loose on the country, (to use his own words,) is to abolish the use of gold and silver as a circulating medium; and to erect human labour into a standard of value, in order to prevent the rise and fall in the price of commodities, which are to be bartered according to the quantity of labour contained in each. Spade husbandry is to be substituted for the plough and harrow. The minute divisions, and sub-divisions of labour, by way of enlarging the minds of his villagers, are to give place to the plan of every man producing an article completed by himself. And they are all to work by turns at different trades, in order to prevent the bad effects upon health, by remaining always in the same position, and employment; as well as to give every one his just share of the agreeable, and disagreeable occupations. And finally, the government of each parallelogram is to be a committee, consisting of all the persons between the ages of 35 and 45.

Such are the outlines of Mr Owen's new plan of society, "by the adoption of which," he says, "the vicious, the idle, and the pauper, shall be made virtuous, industrious, and independent." He offers to "exchange their poverty for wealth; their ignorance for knowledge; their divisions for union;" and he

farther adds, that "he has promised far less than will be realized."

We will now examine the various items of which the plan consists; and endeavour to show, that separately considered, they are calculated to injure, and not to benefit society.

I mean to pass over the parallelogram form of Mr Owen's villages, which he says is better than any other, without assigning a reason, according to his usual custom, why it is so. Also the size of the farms, with only observing, that the largest, viz. 3000 acres of arable land, would be rather inconvenient for cultivation, in consequence of the distance between the dwellings of the labourers, and its remote parts.

We shall also pass over a variety of the less important inconsistencies,* and proceed to inquire into

* Some of the inconsistencies alluded to in the text, are as follow:—Mr Owen, in one part of his report states, "that each association, generally speaking, is to create for itself a full supply of all the necessaries, comforts, and conveniences of life." This can only be accomplished, by each parallelogram having labourers engaged at all different employments. At another part he says, "the villagers are to take their meals all together, at the same time and place;" at another part, he says, "that at meals, the villagers will all be clean, well dressed, intelligent, and possessing benevolent dispositions, all of which combined, will give a proper zest to the entertainment;" and at another part, "that they are all to work by turns at different trades, in order to give each his just share of the agreeable, and disagreeable employments."

But how incompatible are these different parts of his plan with each other. How can those, who are digging the remote parts of a farm of 3000 acres of arable land, take their meals at the same time and place, with those who are working in the immediate vi-

the nature of his system of education, which is considered the only part of his plan not totally irrational.

Mr Owen tells us that the success of his arrangements, will depend upon the manner in which the infants and children shall be trained, and educated, in his two schools ; " for," says he, " men are, and ever will be, what they are, and shall be, in infancy and childhood."

The fundamental principle in his essays on the formation of human character, and which pervades almost every page of his writings, is that the character of man is entirely dependent upon education ; that it is formed by his predecessors for him, and that therefore he may be made to acquire any character they choose. Here Mr Owen's error originates in not perceiving, that man has received a character from the hand of nature, which cannot be eradicated ; though, as every body knows, it may be operated upon to a limited extent by his predecessors. Man, like every other animal, is born with the instinctive principle of acting towards his own gratification, according as his reason directs. This principle, which

cinity of their eating apartments ? Or how is it possible, that men engaged at all different kinds of dirty employments can appear clean, and well-dressed at every meal ? Then again, what a number of suits of clothes must each individual possess, in order to be able to equip himself for each kind of employment. Or, if an extensive wardrobe be deemed unnecessary, how unsuitable would the dress of one trade be for that of another ! Then how impossible would it be for each person, to qualify himself for working in rotation at each different trade, and employment ! How unsuitable to the limited capacity of man, and the short term of his earthly existence !

is the source of all actions good and bad, is influenced by circumstances, which it is frequently impossible for man altogether to control, or even to predict. Providence foreseeing, that the principle of acting with a view to our own gratification, if left unrestrained, must lead to confusion, has wisely provided a check to its abuse. In man accordingly vindictive principles are implanted, which not only excite him to resist aggression, but to punish the aggressor; and this is the check which nature has prescribed in order to control, and direct the selfishness of mankind, so as to prevent one from trespassing upon the rights of another. Selfishness thus restrained, excites us to pursue our own happiness according as reason and experience direct, without abridging that of others. Human laws with punishments annexed to their violation, are founded upon the same principle; and beneficially supersede in society the exercise of vindictive feelings, which is found in some measure destructive to human happiness. Laws are useful in protecting the rights of individuals; and in producing confidence in the transactions between man and man. They exist in every civilized nation, and are absolutely necessary for the maintenance of peace and order in society. Mr Owen, however, going upon his erroneous principle, that mankind have no character but what they are taught, considers all the natural checks to the tendency of man to encroach upon the rights of his neighbour, as useless, and unnecessary. He tells us, that "those laws which enact punishments for a very great variety of actions, which are designated crimes, are palpably absurd, and unjust." But let

us hear the substance of Mr Owen's plan of teaching mankind in order to prevent crimes.

In his essays on the formation of human character, he says, " That each child at two years of age, on his entrance into the play-ground, is to be told in language which he can understand, that he is never to injure his play-fellows ; but, on the contrary, he is to contribute all in his power to make them happy. This simple precept will effectually supersede all the errors which have hitherto kept the world in ignorance." By this I understand, that Mr Owen means, if what he says has any meaning, that this simple precept, (which is very good so far as it goes,) will effectually supersede all the laws and measures which are adopted for preventing crimes. But Mr Owen goes on to say, in the same unintelligible strain, " Thus, by merely attending to the evidence of our senses respecting human nature, and disregarding the wild, inconsistent, and absurd theories, in which man has been hitherto trained in all parts of the earth, we shall accomplish with ease and certainty, the supposed Herculean labour of forming a rational character in man, and that too, chiefly before the child commences the ordinary course of education."

The inadequacy of the proposed means to accomplish the end of preventing crimes, is too obvious to require comment. But it may be observed, that the propriety of inculcating good moral precepts on the minds of youth, is by no means new. The efficacy of moral precepts in conjunction with good example, has been admitted to a limited extent, and their propriety recommended by every moralist from the days

of Solomon to the present time. To take measures in order to increase the difficulties of committing crimes, and to remove the temptations to commit them so far as is practicable, but which is very limited, is also obviously proper. In addition however to these, the adoption of measures in order to counteract the temptation to commit crimes by the dread of punishment, is not to be overlooked. This, as I have already shown, is the means which nature points out; and nature always employs the simplest, and the most efficient means for accomplishing her ends. The innate disposition to resist aggression, and to punish the aggressor, is the principle which nature has implanted within us to teach morality; and which imperceptibly tends to beget moral habits among mankind. Laws are found to be efficacious in preventing crimes, because they are in accordance with nature's plan. Good example, and moral precepts, are but aids to nature's directions; and when their efficacy is compared with the simple, and effective plans of nature, they are found to sink into total insignificance. Man is a being whose actions are governed by selfish motives, and when these tempt him to encroach upon the rights of his fellow-creature, they require counteractives which operate upon his selfish consideration of future consequences, with at least equal power. To adopt therefore with Mr Owen, a moral precept of man's invention, in the hope that it will altogether prevent crimes; and to abandon the instinctive principle of resisting aggression, and punishing the aggressor, and every thing in accordance therewith; would be to disregard the dictates of na-

ture, and experience; and to betray the grossest ignorance of the influence of motives, in exciting, and in restraining human actions.

But let us inquire farther into the method of teaching, and what the children are to be taught.

In his essays on the formation of human character, he says, "The precept that was given to the child of two years old, on coming into the play-ground, 'that he must endeavour to make his companions happy,' is to be renewed and enforced on his entrance into the school. And in addition to the knowledge of the principle and practice of the above-mentioned precept, the boys and girls are to be taught in the school to read well; and to understand what they read; to write expeditiously a good legible hand; and to learn correctly so that they may comprehend, and use with facility the fundamental rules of arithmetic. The girls are to be taught also to sew, cut out, and make up useful family garments; and after acquiring a sufficient knowledge of these, they are to attend in rotation the public kitchen and eating-rooms; to learn to prepare wholesome food in an economical manner, and to keep a house neat and well-arranged." In another part of the same work he has the common sense to recommend, that the national plan for the formation of character should include all the modern improvements in education, without regard to the system of any one individual. All this is good enough, but it contains nothing new. When these ideas were published, Mr Owen's original views seem to have been only in their infancy. In his subsequent writings, however, we find that he has got into his head

peculiar notions on education, which we shall hear from himself. "Children," he tells us, "are to be trained systematically to acquire useful knowledge by means of sensible signs, whereby their powers of reflection and judgment, may be habituated to draw accurate conclusions from the facts presented to them. Teaching by sensible signs is founded in nature, and will supersede the present defective and tiresome system of book-learning."

Upon visiting New Lanark, in May, 1825, I found exhibited there an expensive system of education, partly established, and partly in preparation, in accordance with the preceding description of teaching by means of sensible signs, the leading features of which I will now describe, and what is new will criticise.

Children, before being learned to read their native language, were taught from the mouth of a teacher, geography, natural history, botany, and general history. Geography was taught with the aid of globes and maps, as it is everywhere else. Natural history with the usual assistance of miniature pictures of the different animals: a familiar anecdote being told by the teacher concerning each, in order to give the child a knowledge of the nature of the animal. Botany was taught by means of painted representations of plants, which, where the plants themselves cannot be conveniently exhibited, is a usual substitute. General history was taught by means of striped paintings, filled up with small pictures consisting of groups of human figures, which were intended to represent historical incidents; and nations were distinguished from each other by stripes of dif-

ferent colours. Reading was taught according to the Lancasterian system; though I was informed, Mr Owen preferred Dufief's. Dancing and singing were taught similarly to the common methods.

The first thing that is new in this system of education, is deferring to teach children to read, till they have first acquired a knowledge of geography, natural history, botany, and general history. This alteration in the order of education, appears to be inferior to the ordinary arrangement. By the time children are capable of learning geography and botany, they are quite able to learn to read, and, as is proved by experience, of doing so in as short time, and with as little labour, as they are at any after period of life. One advantage of learning to read first, is, that it reduces the cost of education. Children so taught give comparatively little trouble to a teacher in afterwards learning geography, natural history, or any thing else. By the aid of a book, lessons may be prescribed, and they thereby in a great measure teach themselves. The familiar anecdote which is told by a teacher, in order to give a child some idea of the natural history of an animal, can be as intelligibly told by a book; and with this additional advantage, that while the child is gaining a knowledge of the nature of the animal, it may also be learning to read.

It is sometimes contended by those who are in favour of deferring the teaching of children to read, that as knowledge consists only in the possession of ideas, of which words are merely the signs, children should first be taught ideas, and then language to express them. But let it be recollected, that lan-

guage either spoken, or written, is the instrument of communicating ideas; and that without it, we have almost no means of teaching. Those who wish first to teach children ideas seem to think, that they acquire none but what they are taught by their fellow-creatures; whereas, they are constantly acquiring ideas for themselves, from the time they come into the world. Even the names of things, with the things themselves, and words expressing ideas, with the ideas themselves, from hearing them applied, become in early life gradually and imperceptibly so closely associated, that language either spoken, or written, (when they have learned to read,) immediately suggests the idea, and the idea the language.

It is imagined by some that teaching by means of sensible signs, even in learning to read, is proper so far as it can be introduced, in order that children may learn to understand what they read; and, to use Mr Owen's language, "that their powers of reflection and judgment, may be habituated to draw accurate conclusions from facts presented to them." Thus the miniature figure or picture of a horse is to be attached to the word horse, in order that the child may have an idea what the word horse means; a table to the word table; a chair to the word chair, &c. But how very limited must such a system be! A few names of things is all that can be so described. Besides, children, who are apt to understand every description in the literal meaning, and just as it is represented, instead of being able to form just conceptions, or draw accurate conclusions from such pictures being presented to them, provided they had not pre-

viously acquired correct notions of what a horse, a table, or a chair meant, would be led to form most erroneous ideas concerning these, as well as concerning the shape, colour, and size, of all other objects. This would partly arise from imperfections in the arts of drawing and painting ; and partly in consequence of the miniature size in which all the larger objects of nature, would necessarily have to be delineated. What kind of accurate idea could a child form of the bulk, and strength of an elephant, from the picture of one the size of a mouse? Or of the height of a mountain 27,000 feet high, from a conical drawing twelve inches in length ? Or what correct ideas of nations could it form, from large pictures divided into stripes of different colours ? Neither man nor beast is left to derive a knowledge of external objects from such imperfect sources. We are born with faculties which instinctively take cognizance, and form ideas of objects, and their qualities, from the actual things themselves; and not from imperfect representations. Long before a child can begin to learn to read, it knows the name, and appearance of all common objects. It knows what the words horse, chair, and table mean, as soon as spoken, or as soon as it can read the word, without the explanation of miniature pictures. And hence the reason, that a child taught by means of sensible signs, can form ideas of objects, and draw conclusions, in no degree more accurately, than one taught upon the old plan, without any such assistance.

The only other new part of Mr Owen's system of education, is his teaching of general history by means of large paintings, which contain a confused assem-

blage of small pictures. Different nations are represented by stripes of different colours. And the dates being marked on the margin, the periods of the commencement, the increase, the decrease, and the extinction of nations, which are almost the only points they describe intelligibly, are represented by the commencement of the coloured stripe; its increase, and decrease in breadth; and its extinction. A few other disconnected historical events in the form of small pictures are introduced, but these being necessarily represented in an extremely imperfect manner for conveying instruction; and having no printed key or explanation, require the aid of an interpreter in order to be understood. Printed chronological tables of remarkable events, seem to be superior to such painted ones in several respects. They are much easier understood, and the information obtained from them is therefore less liable to error; they are more easily referred to; more portable; and less expensive.

Besides, what is useful in the study of history is not only totally omitted in Mr Owen's historical maps, but it is impossible that it can be intelligibly represented in any such way. To know that a number of disconnected events have taken place in the world, is of very little importance. The useful departments of history consist in tracing the chain of causes and consequences in the rise, progress, and decline of nations; in exhibiting the effects of the policy of different governments; and in pointing out the influence of laws, institutions, beliefs, customs, and manners upon the character of mankind in different ages and nations. By acquiring such historical knowledge,

the reasoning powers of man are improved; a thorough and extended acquaintance with human nature is obtained; and the welfare of mankind is essentially promoted. History should teach us to anticipate the future by a knowledge of the past. It should teach statesmen to avoid the errors of their predecessors, and to adopt a line of policy, and to frame laws and institutions, calculated to promote individual, and national wealth. It should teach mankind religious toleration, and to renounce all beliefs but such as are consonant to reason and common sense. And by freeing us from prejudices, which seem to be naturally in favour of our own customs and manners, should pave the way for the adoption of those which are most favourable to human happiness. Such are some of the useful purposes which historical knowledge should promote: but the painted historical narratives, exhibited at New Lanark, can answer no such ends. They are better fitted for show, than use. As instruments of communicating historical information, they are found, when carefully examined, to be extremely defective, and unintelligible. Only a very few disconnected incidents, such as battles, murders, and deaths, can be represented by them; and these so very imperfectly, that their causes and effects are not only left unnoticed; but even who the parties represented in the picture are, is unintelligible, without the verbal explanation of a teacher.

Signs, or hieroglyphics on blank maps, representing the different kinds of religion, and the diversified forms of government established in different parts of the world, is another of Mr Owen's useless applica-

tions of his intended general system of teaching by means of sensible signs. Where the English language is spoken, the word Christian, or Mahometan, is more generally understood, and is as easily inserted on a blank map of Europe, as a painted figure of a cross, or of a crescent, which are among the most intelligible of this class of sensible signs.

Man, very soon after he comes into the world, begins to acquire a knowledge of surrounding objects by means of material instruments adapted for the purpose. And by hearing language spoken, he imperceptibly acquires a knowledge of its meaning, and learns to apply it himself. Words are the usual signs whereby mankind communicate their ideas; and all other signs of ideas, which might vary in every different seminary, according to the taste of the teacher, are never used in after life. Teaching indiscriminately by means of sensible signs, may be useful in the education of the dumb, who have no bettter means of receiving instruction. But with those who possess the faculties of hearing, and of speech; and so long as mankind converse by means of words, and not signs; and so long as histories are printed, and not painted; it is surely most advisable to teach children to understand, and to practise the method they must afterwards adopt.

The only point in this system of education which merits consideration, is the influence which graphic description, or picture delineations of historical facts, or occurrences of any kind, have in assisting the memory. Facts so represented, whether exactly resembling the things themselves or not, on account of

the mental associations thereby formed, are known to have some little effect, in leaving a more lasting impression upon the memory, than simple narrative. Mnemonical systems, or arts of memory, have all been formed upon the effect observed in assisting memory, by means of mental associations of ideas, with time, place, and real, or imaginative pictures. But these, like Mr Owen's painted narratives, when applied to the retention of general knowledge, or the cultivation of our reasoning faculties, have all been found to have either no effect at all, or one that was extremely limited and imperfect in its application. Hence the reason why none of those who have attempted to take advantage of mnemonical systems, have ever been observed to possess more practical knowledge, or stronger reasoning faculties, than their fellow men. And hence the reason why no greater prodigies of learning and genius have appeared at New Lanark, than have appeared at Old Lanark.

Though I have attempted to show that Mr Owen's historical maps are of little or no value, I do not mean to say that every thing of that kind is useless. The plates in Thomson's Atlas of the comparative heights of mountains, and lengths of rivers, and maps representing the different animals inhabiting their native quarters of the world, and pictures representing the costumes of different nations, convey to the mind at a glance, an interesting, and at the same time, a clearly intelligible description. Pictures are found to be important aids to descriptions in correcting our notions of places, animals, objects, and scenes of every kind which we have not seen. And hence they

have been employed by natural historians, anatomists, botanists, travellers, and descriptive writers, and teachers of every kind. Even painted historical narratives, though perhaps first used by Mr Owen in the education of children, are not his invention. This mode of transmitting a knowledge of remarkable events according to Dr Robertson, seems to have been employed by very rude nations, who had no better method, prior to the invention of writing. But when this art was introduced, it superseded the use of painted narratives, just as a more useful, more convenient, or cheaper method of communicating and transmitting knowledge, as well as of doing every thing else, will always supersede that which is less so.

For the purpose of encouraging assiduity and attention on the part of pupils, the excitement of emulation by means of rewards, and more honourable situations, has been effectively had recourse to. But Mr Owen, without showing how, says "that the present mode of education, of exciting emulation by hope of reward and dread of punishment, is not only productive of all the bad, but destructive of all the good qualities in human nature, and in his system of education," he again tells us, without showing how, that "rewards and punishments are to be superseded by a knowledge of the science of the influence of circumstances over human nature."

Every person of ordinary information knows that rewards and punishments, particularly the former, have influence in accelerating the education of children, by making them attentive and studious; and that the practical adoption of rewards and punishments is

founded upon the knowledge of that influence. But Mr Owen proposes to do away with these, which are amongst the most effectual means yet discovered, for accelerating education.

But let us next hear the effects of his mode of tuition.

Mr Owen says, that by his system of education "by means of sensible signs, infants and children will acquire more real knowledge in one day, than they can acquire by the old system of books in many months, also the best habits and dispositions, &c. And by the time they are twelve years of age, they will have acquired a knowledge of all the arts and sciences of which the present age are possessed; and having acquired a knowledge of the science of the influence of circumstances over mankind, they will be entitled to the name of rational beings."

Such a hyperbolical description refutes itself. Suffice it to say, that though Mr Owen frequently throughout his writings treats the rest of mankind as irrational beings, merely because they have not been educated according to his system; yet after giving it a careful examination, it is difficult to perceive any good reason, why his rational beings of twelve years of age, can be any thing else than children after all. And instead of having acquired a knowledge of all the arts and sciences of which the present age are possessed, they are unable to speak or write two sentences together, on any subject, either sensibly or grammatically. And of this no better evidence need be adduced, than that composition, which, after reading, writing, and arithmetic, is the most useful part of education

for improving the mental faculties, is totally overlooked in Mr Owen's system.

The dress of the villagers is to be loose, and similar to that of the ancient Romans, or modern Highlanders. Mr Owen says, "the Romans and Highlanders appear to be the only two nations, who adopted a national dress on account of its utility, without, however, neglecting to render it highly becoming, and ornamental." But is not the dress of every nation useful, and at the same time partly ornamental? And in what does the superior utility of the Highland garb over that of other civilized nations consist? In support of the cold uncomfortable dress of the Highlanders, Mr Owen seems to think that clothing is of no permanent use in keeping the body warm. "Additional clothing," says he, "makes one feel warmer at first, but that the body soon becomes proportionally unable to resist the cold, and one soon feels as cold with the additional clothing, as though it had never been put on." That habit has in this case some effect must be admitted. But that clothing, and additional clothing, does not assist mankind in resisting the effects of cold, and in rendering changes of temperature less felt, is contrary to universal experience, and to the practice of all nations founded thereupon. The human frame is possessed of an internal active power of producing, or rather of collecting and evolving caloric, which, by the body's being placed in a cooler atmospheric temperature, than the corporeal heat necessary for the support of life, is getting constantly abstracted. The body has the power upon demand, of increasing its production of heat, and of

retention thereof, to a certain extent, but not to one that is unlimited. When the abstraction of heat becomes greater than the power of production, the temperature of the surface of our bodies is gradually reduced below what is necessary for the support of life, and health; and if continued, disease, and death would soon be the consequence.

It is ascertained that the degree of heat which is most agreeable, is also that which is most healthful; and in proportion as either heat or cold become disagreeable, so do they become unwholesome, and injurious, not only to those who enjoy health, but to such as labour under disease whatsoever be its nature. A certain degree of bodily temperature, varying in different kinds of animals, seems necessary for life; and the sensations of heat and cold appear to be implanted in man, and animals, in order to direct them instinctively towards the preservation of their existence. It is also ascertained that not only different men, but the same men, at different periods of life, and in different states of health, as well as when undergoing different degrees of bodily exertion, require different degrees of clothing. Thus the aged, the infirm, and those whose occupations preclude bodily activity, require more clothing than the young, the vigorous, and the actively employed. And hence the adoption of a uniform, cold, or warm dress, as Mr Owen directs, would be to oppose the dictates and warnings of nature; and which, in proportion as it diminished bodily comfort, would tend to injure the health and happiness of mankind.

Mr Owen seems even to go the length of indirectly

recommending the propriety of going naked, or at least approves of much bodily exposure, for the maintenance of virtue, and sexual delicacy. "Sexual delicacy and virtue," says he, "will be found much higher in nations, among whom the person from infancy is the most exposed, than among those people who exclude from sight, every part of the body, except the eyes." This leads me to consider in what sexual delicacy consists. Sexual delicacy appears to be a sentiment, which manifests its existence, by inducing us to screen our nakedness from observation. Its intention is to protect the virtue and chastity of youthful innocence. And nature, we may rest assured, teaches us in this, as in every other instance, to take the simplest and the best means for producing the effect. When the natural guardians of our moral sentiments are removed, those feelings soon become depraved, or altogether lost. Hence the reason why improper pictures, scenes, or theatrical representations, soon blunt this youthful feeling. And I will venture to add, without the proof of ocular observation, that where total nakedness exists, if such a nation is any where to be found, the sentiment under consideration is as little or no more felt, than it is by the beasts of the field.

Having now considered Mr Owen's measures for the acquirement of incomprehensible wisdom, and the production of an unlimited increase of happiness and morality, we will next examine his three grand measures for the advancement of national prosperity, and the production of incalculable wealth, even until it become so abundant, that any farther increase to

it will be considered useless, and not to be desired.

The first measure whereby Mr Owen proposes to let prosperity loose on the country, (to use his own words,) is the abolition of the use of gold and silver as a circulating medium, and the erection of human labour into a standard of value, thereby preventing the rise and fall in the price of commodities, which are to be bartered according to the quantity of labour contained in each.

Mr Owen says, " that gold and silver have already been found unable to perform the task that ignorance assigned them, for, in 1797, government were obliged to enact that bank of England paper should become the legal standard of value; a striking proof," says he, " that society may make any artificial substance, whether possessing intrinsic worth or not, a legal standard of value." And he farther adds, " that any attempt of the bank to resume cash payments, will prove as vain as to try to restore a full grown bird to the shell in which it was hatched, or to make the clothes of an infant cover a giant; for the improvements in society have equally outgrown the late system of cash payments."

The exchangeable value of gold and silver, I need hardly remark, is dependent upon the value of the amount of labour requisite to produce them. Thus, the value of the amount of labour requisite to produce a guinea, is, generally speaking, exactly equal to the value of the amount of labour requisite to produce a guinea's worth of cotton, sugar, or of any other commodity. If a plan was found out for producing gold

with one half the labour it takes at present; or, if the currency was alloyed with a base metal, so that it only contained one-half its previous amount of gold, (as has been done by some of our former kings when they wished to reduce the real amount of their debts one half, though the nominal amount remained as before,) a guinea would only possess one-half its previous value; and would only purchase one-half of its previous amount of cotton, sugar, or any other commodity; the labour of producing these articles remaining as before. Or, *vice versa*, the amount of labour requisite to produce cotton, sugar, &c., being reduced one-half, while that of producing gold remained unchanged, a guinea would purchase twice the amount of cotton, sugar, &c., which it previously did. Labour, therefore, is the cause of value; and a guinea, or gold, contains the labour in it equal to its value. Bank-notes are only valuable, in proportion as the issuers of them are bound to give something valuable for them, upon their being presented for that purpose; or according as it is likely that something valuable may immediately, or ultimately be obtained for them. The case alluded to by Mr Owen of the bank of England being absolved from payment of their notes in specie, was merely a temporary measure. And the bank has since resumed cash payments, which Mr Owen, with all his knowledge of the science of the influence of circumstances over human nature, said, " was as impossible as to restore a full grown bird to the shell in which it was hatched, or to make the clothes of an infant

cover a giant; for the improvements in society had equally outgrown the late system of cash payments."

In reality there is no invariable standard of value in existence. In exchange, labour as well as gold, and every other article, rises and falls according to the supply and demand. But that gold and silver are well qualified for a circulating medium, or for being a standard or measure of value, if you choose so to speak, has been most satisfactorily acknowledged among all nations, by their universal adoption of them. And though Mr Owen says they have been found unable to perform the task that ignorance assigned them, nothing has yet been discovered that could so well answer the purpose. Though bank-notes of different amounts are generally used in this country, still it must be recollected, that their value depends upon their being the representatives of gold; and upon responsible persons being bound to pay them in such, when presented for payment.

The use of a circulating medium is to render the exchange of commodities, or buying and selling, easy. By being possessed of a portion of the circulating medium, gold and silver, we can go wherever we choose, and purchase whatever we want, from whoever has it for sale. But if all circulating mediums were abolished, and the bartering of commodities according to the quantity of labour contained in each introduced, as Mr Owen proposes, we would not only have to find out a person who had the article we wished to purchase, but one who was desirous of exchanging the article we wanted, for that which we had to give for it. How much more inconvenient would

such a system be than the present one of a gold and silver currency! and how much more tardy and doubly difficult the transactions of merchandise! Without a circulating medium, or common measure of value, intercourse with foreign nations, and even travelling beyond the limits of our own parallelogram, would be attended with extreme difficulty. Who could carry with him food and every thing else he required, or a sufficient supply of articles to exchange for every thing he wanted? Even though he had a supply of exchangeable articles, if he had not food also, he might starve before he could fall in with a person, who would barter provisions for any of the articles he had to give for them.

The next measure by which Mr Owen proposes to enrich the country, is to cultivate the soil with the spade, instead of the plough and harrow.

Owing to my ignorance of agriculture, I am unable to state the difference of productiveness, and of expense, attending these two methods of cultivation. But if we take into consideration the knowledge of spade husbandry that exists, (for it is no new discovery,) and the interest that every one has to adopt the most profitable mode of cultivation, we are warranted in drawing the conclusion, that the superiority of production by the spade cultivation, does not compensate for the saving of labour by the plough. Or, in other words, that the surplus produce gained by means of the spade plan, would not support the additional number of labourers thereby requisite. That this is by no means doubtful, is evident from the universal use of the plough; whereas, if it were in the least degree

uncertain which plan was the most profitable, both would be in general use. But let us hear what Mr Owen says. After telling us most liberally, according to his usual custom, of the immense, and miraculous advantages that would result from spade cultivation, he says, " that the present race of farmers are not qualified to take advantage of it, because they have not a knowledge of the science of the influence of circumstances over human nature." But how a knowledge of this science (which seems to be his constant loop-hole in cases of difficult explanation,) would qualify farmers to cultivate the soil, he leaves the reader to discover.

The next important measure which Mr Owen proposes, for the benefit of mankind, is to abolish the minute divisions, and sub-divisions of labour; and to make every man, by way of enlarging his understanding, produce an article completed by himself. He also proposes that every one should change his employment alternately, in order that each might have an equal share of the agreeable and disagreeable, the healthy and unhealthy occupations.

It need hardly be remarked, that these measures, like those which we have already considered, would tend to impoverish, instead of enriching society. Every means whereby an article can be produced at less expense of labour, is a saving of that portion of labour to the community, which may be used, if required, in some other beneficial way, such as, in the production of some other useful article. And in like manner, every means whereby a given amount of any manufactured article can be produced by fewer work-

men, is a saving to the community of the labour of the workmen thereby rendered superfluous. Practice at one trade, or in any particular department thereof, gives facility and expedition in working; and on this account the sub-dividing plan, by which a man's hand is always engaged at the same occupation, is found to be the most productive, and that which brings manufactured articles cheapest to market. Hence the reason that as nations advance in wealth, (that is, in the means of producing the necessaries and luxuries of life,) minute divisions, and sub-divisions of labour, (as are exemplified in the cotton mills formerly under Mr Owen's superintendence at New Lanark,) are more and more introduced into manufacturing establishments.

Mr Owen's additional proposal, that each person should work in succession at every different trade, would still farther diminish the productive power of society. The facility and expedition acquired by each individual continuing at the same occupation, would in this case not only be lost, but the time, labour, and study, spent in gaining a knowledge of each trade, so as to be able to work at them; and the inferiority of the workmanship, would increase with the number of occupations which each individual had to learn, and practise. Such a system might make the villagers Jacks of all trades, but as the proverb farther tells us, they could be masters of none.

Notwithstanding the obvious nature of the foregoing remarks, Mr Owen, in his usual strain of unintelligible declamation, says, that "minute divisions of labour, and division of interest, are only other terms

for poverty, ignorance, waste of every kind, universal opposition throughout society, crime, misery, and great bodily and mental imbecility;" and he farther adds, that "these things are plain and obvious to every capacity." But how a minute division of labour is only another term for poverty, ignorance, waste of every kind, &c.; must be left to those, who are skilful in interpretation to explain.

The government of each parallelogram is also quite original. It is to consist of a committee of all the persons between the ages of 35 and 45; and their business is to plan the operations of the villagers. Thus it appears, that all the persons in the prime of life, and who, on that account, are ablest to work, are to have all the rest that is going. How much better would it be to leave this less laborious duty to persons of more advanced age, rather than doom those to perpetual toil, whose bodies, in consequence of age and other infirmities, were becoming unfit for action, and required rest. No mention is made of laws. Indeed what could be the use of laws, which, on account of having no penalties attached to their violation, they had no means of enforcing. Such a government would be powerful in point of numbers, but without power in every other respect.

It is somewhat amusing to notice the numerous and inconceivable effects, which a knowledge of the science of the influence of circumstances over human nature, is to produce, besides those already mentioned. "It is to put an end to wars; it is to create new mental powers;" (phrenologists would then have to discover a few more organs,) "it is to

supersede," what Mr Owen calls "the present truly irrational system of individual rewards and punishments; it is to dispel ignorance, to prevent crime, to put an end to misery, and to open a new era to the human race, in which real happiness will commence, and perpetually go on increasing through each succeeding generation. And although the characters of the present generation have been formed under existing circumstances, which," he says, "are altogether unfavourable to happiness, yet having acquired a knowledge of this science, they will be placed in circumstances so agreeable to human nature, and so well adapted to all the acknowledged ends of human life, that those objects of anxious desire, so ardently sought for through past ages, shall be secured to every one, with the certainty of a mathematical procedure."

Such are some of the effects which Mr Owen says "will be produced by a knowledge of the science of the influence of circumstances over human nature; and a knowledge by which these can be controlled, so as to direct mankind," to use Mr Owen's own words, "to the production of universal good or universal evil." "Society," he goes on to say, "are at present governed by circumstances; whereas, by his system, society would govern circumstances. Character is formed for, and not by the individual. Children from birth are continually subjected to impressions derived from external circumstances, which impressions, when combined with their natural qualities, do truly determine the character of the individual through

every period of life;" * and he says, " from a knowledge of the science so often named, man will be able to form good or bad characters, which will continue through life, by the education and impressions which are made upon infants; for men are, and ever will be, what they are, and shall be, in infancy and childhood;" and he farther adds, " all the bad qualities will be prevented, by excluding all notions of reward, punishment, and emulation, from the education of children."

It would be tedious to examine particularly every idea contained in these quotations. But why does not Mr Owen explain this science; and how a knowledge of it would be productive of so many beneficial effects to the human race? If Mr Owen means any thing at all by a knowledge of the science of the influence of circumstances over human nature, it is only what is called in common language, a knowledge of human nature. That the character of man, or the manifestations of his character, are very much affected, and influenced by external circumstances, from his earliest years to the end of his days, is known and observed by every one. Laws for the prevention of crime and the protection of virtue and property, are founded upon a knowledge of the circumstances that influence human conduct. Punishments annexed to the breaking of laws, and a vigilant police for the detection of criminals, in order that punishment may follow, are measures invented by human wisdom, and

* The sentence immediately preceding the asterisk, is unobjectionable; but in what follows, Mr Owen again deviates into his erroneous notions.

found by experience to be well calculated to modify or alter circumstances, so as partly to counteract the temptation to crime, and to restrain man from trespassing upon the rights of his neighbour, by making it for his interest so to do. In like manner, rewards and marks of distinction for inventions, or good services, produce circumstances, that are known and observed to operate upon the innate faculties or character of man, so as to stimulate him to act in a way that is considered beneficial to his fellow-creatures; and when applied to the education of children, is intended to induce them to study in order to benefit themselves. Even the beneficial effects produced by religion upon the morals of mankind, are chiefly, if not wholly, dependent upon the circumstance of its holding out the hope of reward to the virtuous, and the dread of punishment to the wicked, thereby controlling circumstances, so as to make it appear to be the interest of man to be virtuous. Thus while Mr Owen intends to control circumstances, he proposes the abolition of rewards and punishments, the most effectual means yet discovered for the purpose, without giving us any idea of what he intends to substitute.

To suppose that character, or the manifestations of character, is no way affected or influenced by external circumstances after the age of childhood, is but one of Mr Owen's numerous and obvious errors. Till this period of life, man displays almost only his original or natural character, derived from his organization, which is even then only partially formed. It is chiefly subsequent to this period of life, and not till

man comes in contact with man; not till he is under the necessity of pushing his way in the world, and of providing for himself, when being more seriously excited to action, and more exposed to temptation than in infancy and childhood, that external circumstances have most effect upon his character. Besides, the powerful influence of habit upon character, which arises from a continuance of the same circumstances, at so young an age as that of childhood, can hardly be said to exist.

That education has some effect in the formation of character, must be admitted; but that it thereupon wholly depends, as Mr Owen supposes, is evidently erroneous. Certain passions and propensities, independent of education and external circumstances, are implanted in man by the hand of nature. The strength of these, arising from difference of organization, varies in different individuals; and to these differences, the diversity of character, must be partly, if not principally ascribed. Among the inferior animals, striking differences of character exist, which can be referred only to difference of organization. We never find the character of a sheep, existing in the shape of a tiger; nor the character of a tiger, in that of a sheep; nor by any training or education can their characters be assimilated, which would be the case, if such differences depended solely upon training, and not upon structure. As it is with different animals, so is it with different men, though not to the same extent; they are differently formed, and therefore possess different characters. No education can make the cowardly, brave; or the stupid, wise, beyond a limited

extent. No education can give the dull, submissive, patient, phlegmatic temper, the violent, commanding, and impatient character of the choleric. Nature has formed them opposites, and no education, nor circumstances, can make them altogether assimilate.

The only original idea of Mr Owen's, that is deserving of a moment's consideration, is that of increasing the national wealth, by all men acting in union for the interest of the whole, instead of each individual acting, as at present, for his own private benefit. Or in other words, that with the same amount of labour, more of the necessaries, comforts, and luxuries of life, would be produced by mankind acting in union for the interest of the whole, than what is produced, by each individual acting separately for himself.

To show that this would not be the case, it may be observed, that all the actions of mankind spring from some motive or other; and that the stronger the motive, the greater, and the more constant, will be the exertion. Self-interest is naturally a stronger motive for industry, than the interest of another, or than the common interest of the community. A man's mental and bodily powers, are called more into action, when his private interest is the motive, than when his private interest is so much divided and diminished, as it would be, by being combined with the private interest of every other member of society. Hence the reason, why piece-work, or payment for the work done, wherever it can be adopted, is always found the most productive plan of employing labourers, and the most advantageous to the employer. And hence also the

reason, why Mr Owen's system of all acting in union for the common interest, would not be so productive as the present plan of each acting separately for himself.

The waste, besides, under a system where all the wealth or produce of the community was common property, would also be greater. A man would not have the same inducement to economize, where his economy would be of no more advantage to himself, than it was to every other member of the community, as he would have, if the whole advantage of his economy was gained by himself. The system would, besides, be unfair, and would consequently be productive of discontent, and disagreement. It would be unjust that the ingenious, the industrious, and the frugal, should not have advantages over those who had no invention, the lazy, and the extravagant. Justice requires, that in proportion to the superior usefulness of the former over the latter, as members of society, they ought to be rewarded. In short, a system founded upon the principle, that every man would exert himself to the utmost of his ability for the common benefit, without possessing the means within itself of rewarding every one according to his exertions, and general usefulness; and without the power of compelling a man to work if he was lazy, and happened not to be inclined; or of inflicting punishment upon any one who injured, or acted unjustly towards the other members of the community; might suit the condition of some imaginary beings, but is not adapted to the nature of man.

In the present natural system of society, every

thing is so admirably adapted to answer the end for which it was intended, and so well calculated for the promotion of the common welfare, that when every one acts for his own individual benefit, instead of acting in opposition to the interest of the community, as Mr Owen supposes, he is acting in union with them in the most effective way for their interest. In proportion, generally speaking, as a man's labour is profitable to himself, so is it beneficial to the community. If any article of consumption becomes scarce, the person who most speedily supplies the demand, while he benefits the community by furnishing them with the article they want, enriches himself, by obtaining an amount of profit or remuneration, proportional to the demand for the article and its scarcity. Thus it is, that private benefit goes along with public benefit; and that when a man is acting with the intention of only promoting his own individual advantage, he is acting in perfect union with the rest of the community for the interest of the whole. Hence the reason why every article of ordinary consumption, can always be got to purchase with but trifling variations in price. And hence the reason, why under the present natural system, which Mr Owen is pleased to call "Old Society," a government consisting of a committee of all the persons between the ages of 35 and 45, whose business is to direct the operations of the community, lest any article should become scarce, is found to be totally unnecessary.

We will now make some observations on the remote consequences of Mr Owen's plan, and endeavour to show that, if universally adopted, instead

of diffusing knowledge, wealth, and good morals among mankind, it would tend to spread, and greatly increase ignorance, poverty, and crime.

It is difficult to perceive any permanent advantage that would either immediately, or ultimately be conferred on society, by the universal adoption of Mr Owen's plan, even though freed from many of its unnatural absurdities and impossibilities, while the disadvantages are both numerous and obvious.

It proposes to abolish punishment, reward, and emulation. The first of these has its origin in the vindictive principles of our nature, wisely and beneficially implanted in man, in order to restrain the improper direction of our selfish feelings. Its abolition could only tend to increase the commission of crimes, by removing the restraint, while the disposition and temptation to commit them, remained as great as before. To maintain order in society, and check the commission of crimes, punishments seem to be unfortunately, but absolutely necessary. Like every thing else, however, (as was the case with the laws of Draco,) it may be overdone. That kind and degree of punishment is best, which, with least severity, has the greatest effect in preventing the commission of crime. In advancing the education of children, its indiscriminate application is at best but doubtful. Slow progress commonly arises more from a want of natural aptitude of apprehension, and capacity for receiving instruction, than from inattention. To inflict chastisement under such circumstances, is but to punish the child for its misfortune, and for what it cannot help. Nevertheless, in the education of chil-

dren, as well as in the moral government of society, punishment of some kind or other is useful, if not absolutely necessary, in order to restrain impropriety of conduct. The utility of rewards is universally acknowledged, and therefore universally adopted. Emulation, which consists in a wish to be considered superior, if not in itself a distinct innate principle, arises naturally and involuntarily in man, and other animals, out of a perception of the superiority and inferiority which they either possess, or suppose they possess, relatively to each other. This principle, which Mr Owen considers so destructive to human happiness, and notions of which he recommends to be so scrupulously excluded from the education of children, is, when properly directed, one of the most effective means for exciting mankind, at every period of life to cultivate their mental faculties, and to acquire bodily accomplishments ; and, in short, is wonderfully calculated to encourage general industry, and the performance of virtuous actions of every kind. There is no doubt that a spirit of emulation or ambition, by the adoption of suitable means, may be either damped, or encouraged : and that it may, in some instances, proceed to an injurious extent, must be also admitted. But its effects upon the whole are decidedly beneficial.

Man, like every other animal, is formed with a combination of instruments and faculties, admirably fitted for the kind of life he is destined to lead. Even self-interest, the ruling principle of our nature, and to which in an extended sense* all our actions

* Self-interest, in the extended sense here and in other passages

can be traced, is found upon examination to minister to the advancement of public good, and general prosperity. For man to attempt therefore by any system, wholly to eradicate or destroy the innate principles of the human constitution; and thereby to improve upon the works of his Creator, would, even if possible, only tend, in all probability, to destroy his moral happiness, and to injure his worldly condition. But to try to root out what Mr Owen considers the bad qualities of our nature, (but which can all be shown to be ultimately productive of good,) by such feeble and inadequate means, as the exclusion of all notions of reward, punishment, and emulation, from the education of children under twelve years of age; or even by any means whatsoever, is just as vain, useless, and unprofitable, as it would be, to endeavour to direct the winds, or to control the tides.

The distribution of the population into parallelograms at equal distances over a country, according to Mr Owen's system, besides being productive of injustice and disagreement, in consequence of the unequal fertility of the soil, would also tend to impoverish mankind. The wealth of a nation is promoted by every improvement in the arts, and every arrangement

alluded to, means the disposition to gratify all our desires and feelings, without regard to whether such gratification is, or is not intentionally directed, so as to promote the happiness of others, provided (which is always the case,) that such is attended with our own personal gratification. Even those affections which may be called generous or benevolent, such as love, friendship, and pity, excite us to action only in proportion to the amount of pleasure enjoyed, or the amount of evil avoided, by immediate, or anticipated feeling.

of society, whereby the necessaries, comforts, and luxuries, of life, are supplied with less labour and expense. According to the present system of society, every individual in pursuing his own interest, fixes his residence where he can most easily find employment; or where he sees the best prospect of bettering his condition. Hence mankind arrange themselves, in the most favourable way for promoting the wealth of nations. Villages, towns, and cities, arise without human foresight or direction, in the most suitable situations for diminishing the labour of mankind, in conducting their commercial transactions. Manufactures, when neither stimulated nor restricted by the ignorance of statesmen, naturally fix their seat, and prosper, where the greatest local advantages are possessed; and commerce takes its direction through those channels, by which the interchange of commodities, throughout the world, can be conducted, and the desires of man gratified, with the least labour and expense. Governments in reality have got no more to do in contriving the most perfect distribution of population, than to allow every individual instinctively to pursue his own interest. And it is evident that every forced arrangement of population, (such as the parellelogram distribution proposed by Mr Owen,) in proportion as it deviated from that which was natural, would diminish instead of increasing, the wealth and productive power of mankind.

An extended survey of the existing arrangement of society, presents a scene of universal harmony. It resembles a machine, the different parts of which are not only admirably fitted to each other; but being

possessed of an inherent power of mutual self-adjustment, every injury which the mechanism can receive, is soon repaired without the aid or direction of human skill. By each individual acting for himself, every comfort and convenience can be procured on the cheapest possible terms; every improvement is adopted; and mutual interest and accommodation are thereby so wonderfully maintained, that we can traverse the earth with ease, safety, and expedition, and scarcely know we are from home.

But under Mr Owen's system, where no law existed to check abuse; no reward for merit; almost no motive to excite exertion; nor mutual interest to induce man to accommodate his fellow-creature; a scene of idleness and discord would be presented, and the symmetry of the machine would be destroyed. Consider how difficult it would be to travel or merchandise without a circulating medium! How weak would be the motive or inducement to roam abroad, under a system where commerce must cease, in consequence of each parallelogram producing all that it required, generally speaking, within itself! How little to gratify the curiosity of man, delighting in novelty and variety, where nothing was to be seen, but the dull, unpleasing uniformity of endless parallelograms! How narrowed would become the field of fame! How discouraging to the cultivation of genius! And, compared with the present state, how insipid the life of man, confined as it were to spend his days within the narrow precincts of a parallelogram, instead of having the world for his stage, and the human race for his audience.

Under Mr Owen's system, where the means and motives for travelling would be in a great measure destroyed, man by losing intercourse with the inhabitants of the rest of the world beyond his own parallelogram, would also lose a knowledge of their opinions, manners, customs, and religious notions. Such a loss would inevitably subject the human mind to every kind of narrow prejudice. For of all things known, travelling, and general intercourse with the world, have the greatest influence in promoting liberality of sentiment; and in dispelling the bigoted ignorance and superstition, which characterize the natives of all remote and insulated nations.

The language spoken by the inhabitants of the different parallelograms, from want of intercourse, (for it is this principally that assimilates them,) would also gradually diversify in accentuation, pronunciation, and subsequently in spelling, till the language of one parallelogram, became unintelligible in every other. And instead of having one language spoken all over Great Britain and Ireland, we should have as many different dialects as parallelograms.

Knowledge under such a system could hardly be expected to advance; for instead of the whole world reaping the benefit of an invention, or improvement in any of the arts and sciences, without regard to where it originated, as in the present state of things, it would likely be confined to the particular parallelogram in which it was discovered. It is even reasonable to suppose, that under such a system, knowledge would be retrograde. It is by no means likely, that every parallelogram would produce men both qualified

and inclined, to keep up the present state of knowledge in all its departments. But it is highly probable, that from want of encouragement given to men of genius, which the system strictly forbids, all learning and study would be gradually abandoned. The human species under such a system, from having no hope of advancement, or of bettering their condition, to stimulate them to exertion, would sink into a state of indolence, ignorance, and stupidity. And from want of exercising, and thereby of improving their mental faculties, would probably degenerate in the course of a few generations, into beings possessed comparatively of weak reasoning powers, whose actions would be governed more by instinct and superstition, than by reason and experience.

The moral influence upon society which the separation of children from their parents at two years of age, when they commence their education; and the effects of the mutual independence that must afterwards subsist between children and parents, under Mr Owen's joint-stock system, may likewise be considered.

In the present state of society, parents are bound by law to support their children according to ability; and they, in their turn, to support their parents when they happen to require such assistance. This reciprocal obligation, however, does not exist merely because it is regarded as useful to society, and on this account enforced by statutory enactment; but because it is felt by mankind generally to be a duty, in the performance of which they experience pleasure, and in the neglect of which they suffer pain. The law,

in this case, properly encroaches upon individual rights, in order to enforce what the feelings common to man, in every age and nation, point out as an act of duty. And so invariably is our individual duty, and public utility connected, that the performance of whatever the common sense of mankind declares to be our duty, is ever found to be practically useful.

Providence, in order that virtue should in some degree receive its reward, and vice its punishment, has so organized the human frame, that the exercise of every benevolent affection, and the performance of every virtuous action, not only gains us the good will of others, but is accompanied internally with pleasing sensations. And on the contrary, that the indulgence of every malevolent feeling, while it sinks us in the estimation of others, occasions pain and uneasiness to ourselves. The knowledge of this equitable ordination, every moralist ought to inculcate. It teaches man, in order to promote his own happiness, to cherish benevolent affections towards his fellow-creature, and to control and restrain those of an opposite character. It is in accordance with this wise provision in the animal economy, that the parent's anxiety, and care for the welfare of his child, becomes one of the sources of his happiness.

It would be out of place here to inquire metaphysically, whether parental and filial affections originate in internal organization exclusively adapted to these purposes, or in the influence of necessarily habitual proximity, and other circumstances, operating upon our reasoning faculties. It must, however, be admitted, that separation and mutual independence, not

only weaken those feelings, but beget mutual indifference towards each other's welfare; and, on the contrary, that habitual intercourse and association, and mutual dependence, and exchange of services, create and cherish, not only these affections, but every other friendly and benevolent feeling implanted in man.

Legislative wisdom is displayed, not in attempting to modify and alter human nature so as to suit ideal states of society, but in adapting laws and institutions to accord with human nature. It is only by such means that the happiness of mankind will ever be promoted. Feelings are the sources in which pleasure and pain originate. They are the forces that impel to action; and the direction of the impulse, guided by reason and experience, is ever towards their gratification. So wonderfully, however, are human feelings adapted to our social condition, that while they instinctively impel us towards their own exclusive gratification, they are secretly and simultaneously directing us to use the means, by which the moral happiness of others, and the prosperity of society, may be best promoted. And laws, institutions, and forms of government, which do not harmonize with the aggregate influence of human feelings throughout society, will ever be more or less inefficient, prejudicial, and productive of discontent.

To separate children from their parents at so early an age as two years; and for children and parents to become mutually independent thereafter, according to any arrangement of joint-stock property, is in opposition to the dictates of nature; and evil instead of good would therefrom result. Such would not only

lessen the number of our sources of enjoyment; but by severing those links, and weakening those affections, that connect the interest, and mutual well-wishes of a family, would reduce man to a friendless state of existence, in which, though he might feel an independent indifference towards all mankind, yet the feelings of all mankind would stand in the same relation towards him. Would our condition be ameliorated by such a change? Would we be better attended in the hour of helplessness and distress, by the hand of a stranger who cared not for us, than by that of a relative? No: the condition of mankind will never be ameliorated by such means. Let us remain as we are. The present is the natural state of society, and that which is most conducive to domestic happiness. It harmonizes with the feelings common to our nature, because it originates in, and is maintained by, their aggregate influence. It interweaves the affections, and connects the interest of successive generations. Parents and children living together as one family, feel mutually concerned in advancing each other's prosperity. The former feel pleasure in educating, and thereby promoting the future welfare of their children; and they, in their turn, impressed with a sense of gratitude and affection, find it a pleasing duty to assist and comfort their aged parents.

There is only one other general view of the remote consequences, that would result from the adoption of Mr Owen's plan for ameliorating the condition of mankind, deserving of consideration; but which alone is sufficient to show its unfitness, for being productive of any ultimate beneficial effects; and enough to prove,

that it, as well as all other systems of equality, would necessarily deteriorate the condition, and thereby impair the happiness of society. The remote consequences alluded to, are those that result from the principles, which, in different states of society, and under different laws and regulations, determine the degree of force with which population presses upon the means of subsistence. As this subject reveals the only means whereby the condition of mankind can be permanently ameliorated, it is of more importance that it should be understood, than any of those which we have been examining. And as the opinions of Malthus, the author of the greater part of the views in question, have been opposed, misrepresented, and treated with ridicule and contempt, by individuals who have neither read his works, nor know what his opinions are; we will consider this department of our subject at greater length, than would have otherwise been necessary.

The following are some of the leading principles, from which the greater part of the Malthusian doctrines may be deduced.

1. The procreative principle implanted in the human species, is stronger than what is necessary to support a stationary population, provided the means of subsistence can be easily procured by the mass of the people; and accordingly, in such circumstances, population tends to increase. Malthus says: "Population invariably increases, where the means of subsistence increase, unless prevented by some very powerful and obvious checks."

2. The average condition of mankind where the

land is all previously cultivated, and the population employed, is lowered, at least so far as food is concerned, by every addition to their numbers. And the augmenting difficulty which the mass of the people experience in procuring the means of subsistence, as their condition sinks, gradually retards, and at length arrests the increase of population.

3. The fear entertained by individuals of making their condition worse by marrying, together with the hope of making it better by remaining single, in some cases prevents marriages altogether, and in others makes them later in life of being contracted; both of which circumstances, by diminishing the number of children born, check the increase of population, and prevent its pressing so hard as it would otherwise do upon the means of subsistence.

That the procreative principle implanted in the human species, is stronger than what is necessary to support a stationary population, provided the means of subsistence can be easily procured by the mass of the people; and accordingly, that in such circumstances population tends to increase, is a proposition that scarcely requires proof. Unless this had been the case, the earth could never have been replenished with inhabitants. Emigration from old-peopled states to a newly-discovered country, must have diminished the population of the former, as much as it increased that of the latter. And colonization of distant uninhabited parts of the earth, could have served no purpose, but that of weakening the parent state, by withdrawing a portion of its inhabitants, without the possibility of filling up the deficiency thereby occa-

sioned. But that the opposite is the fact, is demonstrated by the growth of colonies. Since America was discovered by Columbus in 1492, various portions of that vast continent have been colonized by emigrants from the different states of Europe; and the procreative principle has in three centuries and a half, conferred on that large portion of the globe, a European population.* And this has taken place, while, owing to improvements in machinery and husbandry, and the cultivation of waste lands, the extension of manufactures, the more general employment, and the greater production and diffusion of wealth throughout society, all acting and reacting as instruments, whereby the means of subsistence can be more easily procured by the mass of the people, the population of all the countries of Europe has been simultaneously increasing.†

* Malthus says: "In the northern states of America, the population was found to double itself, for several successive periods, every twenty-five years."

† According to statistical estimates, the aggregate amount of the population of Europe, which is wholly composed of old-peopled states, has increased twenty-eight or twenty-nine millions from the year 1815, to the beginning of 1829. This augmentation is principally to be ascribed to the increased means of supporting a larger population, arising from the causes mentioned above in the text. It may also in part be owing to the cessation of war, to vaccination, to more effective means being taken to prevent the spread of contagious diseases, and to the removal of those causes in which they originate; all of which tend to lengthen the average duration of human life, and accordingly promote the tendency to augmentation without proportionally increasing the moral restraints that check population. In so far as these causes are contributing to increase the population of Europe, they must be proportionally

In support of the doctrine that population tends to increase under favourable circumstances, Malthus says: "The actual increase of the population of the various nations of the earth may be advanced. Do we not see that whenever the resources of any country increase, so as to create a great demand for labour, and give the lower classes a greater command over the necessaries of life, the population of such country, though it might before have been stationary, or proceeding very slowly, begins immediately to make a start forwards? And do we not see in those few countries, or districts of countries, where the pressure arising from the difficulty of procuring the necessaries and conveniences of life, is almost entirely removed; and where, in consequence, the checks to early marriages are very few, and large families are maintained with perfect facility, the rate at which the population increases is always the greatest?"

That the average condition of mankind, where the land is all previously cultivated, and the population employed, is lowered, at least so far as food is concerned, by every addition to their numbers; and that the augmenting difficulty which the mass of the people experience in procuring the means of subsistence as their condition sinks, gradually retards, and at length arrests the increase of population, is a doctrine that is equally incontrovertible. The greater the number among whom the produce of the soil is to be divided, the smaller must be the portion allotted to each. The price of food, like that of every other

tending to deteriorate the average condition of its inhabitants, at least so far as food is concerned.

article, rises with its scarcity and the number of purchasers; and the wages of labour, with the value of its productions, sink with the increase of labourers. An increase of population thus deteriorates the condition of the industrious classes, which constitute the mass of every community, by lowering wages, and raising the price of food relatively to each other.

By statements made by Dr Villermé on the comparative mortality of the wealthy and indigent classes in Paris, it appears that poverty shortens the average duration of life. During the five years from 1817 to 1821, though the annual mortality for the whole of Paris varied in the different years, the relative mortality in the different arrondissements, as noted below, underwent little or no alteration :—

In the	1st	Arrondissement the mortality was	1 in 58
——	2	——————————	1 — 62
——	3	——————————	1 — 60
——	4	——————————	1 — 58
——	5	——————————	1 — 53
——	6	——————————	1 — 54
——	7	——————————	1 — 52
——	8	——————————	1 — 43
——	9	——————————	1 — 44
——	10	——————————	1 — 50
——	11	——————————	1 — 51
——	12	——————————	1 — 43 *

Upon examination, it was found that local influences could not be assigned for the above results.

* The proportions here given are from the deaths *au domicile*, and supply an average for the whole of 1 in 51; but when the mortality in the hospitals (which are chiefly supplied from the poorer districts) is added, the ratio is increased to 1 in 32.

The ratio of mortality was as great in the spots most sheltered from northerly winds, and most open to the sun, as it was in those placed in precisely opposite circumstances. Nor did the water account for the fact.

Neither could the density of the population be assigned as the cause of the results. Upon examination it was found, that in the 8th arrondissement, the mean space allotted to each individual was 48 square metres; and in the 12th, 36 square metres; while the mean space for each individual in the 7th and 4th arrondissements, was only 10 and 6 square metres respectively. If density of population had been the cause of the difference in the ratio of mortality, the mean duration of life should have been shortest in the 7th and 4th arrondissements; whereas, by the above table, in these two districts, the annual mortality relative to the population, is considerably less than the average; while in the 8th and 12th it is the greatest.

Upon farther comparison it was found, that (with the single exception of the eleventh, which could not be well accounted for,) the annual mortality increased with the poverty of the different arrondissements. Those districts being reckoned the poorest, in which the greatest number of untaxed houses were found. Poverty, therefore, in some way or other shortens the average duration of human life. And hence one reason, why the augmenting difficulty which the mass of the people experience in procuring the means of subsistence as their condition sinks, gradually retards, and at length arrests the increase of population.

"The wages of labour," says Malthus, "sink as population advances, till they are just sufficient to maintain a stationary population. In a country where the wages of labour estimated in food are low, and that food is relatively of a very low value, both with regard to domestic and foreign manufactures, the condition of the labouring classes must be the worst possible. Poland, and some parts of Russia, Siberia, and European Turkey, afford instances of this kind. In Poland, the population seems to be almost stationary, or very slowly progressive; and the population and produce are both scanty compared with the extent of territory. Yet, here, corn is in abundance, and great quantities are yearly exported. But it is neither the power of a country to produce food, nor even what it actually produces, that limits and regulates the progress of population, but the quantity which, in the actual state of things, is awarded to the labourer. The demand for labour in Poland is very small, and the condition of the lower classes of society is extremely miserable. The misery of Poland arises from the little encouragement given to industry of any kind, owing to the state of property, and the servile condition of the mass of the people. The population of Poland is composed of boors and large landed proprietors; the produce of the soil which is worked by the former, all belongs to the latter." It need hardly be remarked, that, in the above case, the exported corn serves merely to supply the proprietors of the soil with articles of foreign growth and manufacture, and does not employ the labouring classes in Poland; and consequently does not increase their

means of purchasing food, and the other necessaries of life.

"Population," says Malthus, in another passage, "is necessarily limited by the means of subsistence, and can never increase beyond the lowest nourishment capable of supporting life. It is of no consequence whether a country export corn or not, the population must still be regulated by the real wages of labour, and must come to a stand when the necessaries which these wages command, are not sufficient under the actual habits of the people, to encourage an increase of numbers."

The checks which keep population on a level with the means of subsistence, or rather, in consequence of their joint agency, which keep down population, so that the average condition of mankind is raised considerably above that limit, are classed by Malthus under two general heads: the positive, and the preventive. "The positive checks to population include every cause which destroys life, such as mortality arising from old age, or infirmity; or which contributes to shorten its natural duration, such as accidents, unwholesome occupations, severe labour, exposure to the seasons, extreme poverty, bad nursing of children, infanticide, great towns, excesses of all kinds, the whole train of common diseases and epidemics, wars, pestilence, plague, and famine. The preventive check to population is peculiar to man, and arises from his being endowed with reason, which enables him to calculate the distant consequences of marriage."* The procreative principles implanted in

* Malthus says: "The checks to population are all resolvable

every species of animal, like the reproductive properties of every kind of vegetable, are sufficiently powerful to cause them to increase and multiply. Hence they go on multiplying unless restrained by obvious causes, till the positive checks, viz., the augmenting inability to obtain a sufficiency of nourishment, gradually retards, and at length puts a stop to all farther increase. Animals and plants therefore increase and multiply, till their number is exactly on a level with the means of subsistence, that is, till the quantity of nutriment which they can severally obtain, is reduced to the lowest amount capable of supporting life, and perpetuating the several species, without increase or diminution in their numbers. Malthus from a slight verbal oversight somewhat fails in elucidating his subject, by always seeming to regard population as being on a level with the means of subsistence in any country, at the point where population becomes stationary. But to reason in analogy with the principles which regulate the number of animals and vegetables,

into moral restraint, vice and misery, or the fear of misery. Of the preventive checks, that which is not followed by irregular gratification, may properly be termed moral restraint. Infanticide, promiscuous intercourse to such a degree as to prevent the birth of children, unnatural passions, violations of the marriage bed, and improper arts to conceal the consequences of irregular connection, clearly come under the head of vice.

"Of the positive checks, those which appear to arise unavoidably from the laws of nature, may be called exclusively misery; and those which we obviously bring upon ourselves, such as wars, excesses, and many others which it is in our power to avoid, are of a mixed nature. They are brought upon us by vice, and their consequences are misery."

where their farther increase is restrained only by natural causes, or as Malthus calls them, positive checks, population can never be said to be on a level with the means of subsistence, till the whole community be reduced to live upon the poorest and smallest amount of food capable of supporting life, and perpetuating the species, without increase or diminution in number. Now, owing to the human species being able to calculate the distant consequences of marriage, and of sexual intercourse, population never increases in any natural state of society, till the whole community be reduced to this condition, which, in point of wretchedness and poverty, is the lowest in which they can possibly exist. This leads us to the consideration of the third principle, viz., the preventive check to population, the effect of which is to limit, and arrest the increase of population, so that the mass of the people can at all times command a greater amount of food and other necessaries, than is absolutely requisite for the support of life, and the perpetuation of the species.

That the fear entertained by individuals of making their condition worse by marrying, together with the hope of making it better by remaining single, in some cases prevents marriages altogether, and in others makes them later in life of being contracted; and that both these circumstances diminish the number of births, and thereby prevent population from pressing so hard as it would otherwise do on the means of subsistence, is a doctrine that Malthus has established beyond all controversy. If this was not the case, the whole population would be married by the time they

are 18 or 20 years of age; whereas, we find that of the females who reach maturity, a large proportion die without ever having been married, and without contributing towards the perpetuation of the species. We will only select one statistical estimate in support of the truth of the principle under consideration, and refer to the original work,* where numberless others may be found. The proportion of annual deaths to the whole population on an average throughout the whole of Norway, is only as 1 to 48, while the marriages are as 1 to 130. In Holland, however, the annual mortality is 1 in 23, while the annual marriages are 1 in 64. By comparing the proportion of deaths and marriages in Holland, with that in Norway, we see how much they mutually depend upon each other. Similar comparisons hold good every where. Deaths, by producing vacant livings, and by diminishing the number of consumers of food, and thereby improving the condition of those who remain alive, prepare the way for marriages; and hence it is found, that the longer the average duration of life is in any country, provided the population be stationary, the fewer are the matrimonial engagements relative to the population, or the later they are of being contracted; and the larger is the proportion of females who die unmarried; and *vice versa*.

In like manner, supposing population stationary, whatever tends to increase the average duration of human life, such as vaccination, or in warm climates, the extinction of marsh fevers by the draining of

* Malthus on Population.

marshy lands, diminishes the chance which females have of getting married, and begets customs and habits among the mass of the people favourable to the exercise of the preventive check to population, and of course unfavourable to early marriages.* Upon similar principles, the chance which females have of getting married, is greater in countries where population is rapidly increasing, such as in the United States of America, and also in cities and districts of countries similarly circumstanced, than in those where the population is stationary, or very nearly so.

Supposing the mean duration of human life the same, it is obvious from the preceding observations, that the average condition of the mass of the people at the point where population becomes stationary, must be raised more or less above that at which population is on a level with the means of subsistence, according as the preventive check is more or less effective in preventing and delaying marriages. In order, therefore, to ameliorate the condition of mankind, our endeavours ought to be chiefly directed to the introduction of such laws and arrangements into our civil institutions, as are calculated to beget prospective prudential habits among the mass of the people, whereby the preventive check may be ren-

* That the influence of the preventive check in limiting population, by preventing and delaying marriages, increases with the average duration of life, is demonstrated by the fact, (and many others may be found in Malthus' works,) that the population of Norway, where the mean duration of life is 48 years, is as stationary, without any aid either from emigration or war, as it is in Holland, where the mean duration of life is only 23 years.

dered more efficient in limiting population. "In most countries," says Malthus, "among the lower classes of people, there appears to be something like a standard of wretchedness, a point below which they will not continue to marry and propagate their species. This standard is different in different countries, and is formed by various concurring circumstances of soil, climate, government, degree of knowledge, and civilization, &c. the principal circumstances which contribute to raise it, are liberty, security of property, the spread of knowledge, and a taste for the conveniences and comforts of life. Those which contribute principally to lower it, are despotism and ignorance. In an attempt to better the condition of the lower classes of society, our object should be to raise this standard as high as possible, by cultivating a spirit of independence, a decent pride, and a taste for cleanliness and comfort among the poor." *

In accordance with the preceding recommendations, Malthus, in another passage, says: "Of all the plans which have been proposed for ameliorating the condition of the labouring classes, by increasing their

* The circumstance of Earl Grey's Reform Bill limiting the elective franchise to ten-pound rented householders—a rank which even the lowest class of labourers, by the exercise of industry and economy, may easily attain—may have some slight influence in begetting prudential habits among the lower orders. The elective franchise is now sufficiently extensive for all the purposes of good government; and were it only for the above reason, it ought not to be extended farther. The present constituency are at least as competent to select proper representatives as any lower constituency, and less liable to be bribed, or to be deceived by demagogues and unworthy persons.

prudence and foresight, that of saving banks, as far as they go, is the best. By giving to each individual the full and entire benefit of his own industry and prudence, is the best plan for promoting such habits."

In like manner, with a view still farther to promote a spirit of independence and prudential habits among the mass of the people, life insurances, and friendly societies, which, for a small monthly or yearly contribution, confer a subsequent right to receive assistance in case of need, are worthy of support. Such institutions ought to receive every protection and security which cheap laws, and the power of government can enforce. And as the first duty of every member of society, is to free the community as far as possible from any chance, that he or his family shall ever become a burden to them, tradesmen who connect themselves with such institutions, should be regarded as better members of society, and more eligible for employment, than those who do not.

On the other hand, poor laws, in so far as they beget imprudent habits in contracting marriages, by affording relief and support to the poor and improvident, so do they ultimately tend to lower the average condition of a people. Upon this point, Malthus says: " The effect of the English poor laws may perhaps be to alleviate the intensity of individual misfortune, which benefit is counterbalanced by their spreading poverty over a much larger surface.

" It is impossible to raise the condition of the poorest class by giving them poor's rates, without lowering the condition of those classes above them who maintain their independence, without applying

for parish assistance. If there is only a fixed amount of food for a given population, if by enabling the lowest class to purchase a better share of that food by parish assistance, than what they would be able to procure without assistance, it is evident that the remainder of the food for the rest of the population must be proportionally less, and of course thereby raised in price to the disadvantage of all those classes who do not receive parish aid. The price of corn in a scarcity, will depend much more upon the obstinacy with which the same degree of consumption is persevered in, than on the degree of the actual deficiency.

"An increase in the price of provisions will arise, either from an increase of population faster than the means of subsistence, or from a different distribution of the money of the society. The poor laws tend to depress the general condition of the poor in these two ways. Their first obvious tendency is to increase population, without increasing the food for its support. A poor man may marry with little or no prospect of being able to support a family without parish assistance. They may be said, therefore, to create the poor which they maintain; and as the provisions of the country must in consequence of the increased population, be distributed to every man in smaller proportions, it is evident that the labour of those who are not supported by parish assistance, will purchase a smaller quantity of provisions than before, and consequently more of them be driven to apply for assistance." In another passage Malthus says: "Already above one-fourth of the population of Eng-

land and Wales, are regularly dependent upon parish relief."

The above opinions are legitimate inferences from the principles which regulate population. Yet Malthus, to whom the science of political economy is more indebted for advancement than to any other man save Dr Adam Smith, has been characterized, as well as all his followers, as uncharitable and hard-hearted, for advocating, and believing in the great political truths which he has revealed.

The opponents of the Malthusian doctrines cry out, compare the state of Ireland where no poor laws exist, with that of England where there are poor laws. The difference, however, in the condition of England and Ireland, is totally independent of the existence, or the absence of poor laws. In society, we see that the conduct of one man is much more regulated by a regard to consequences, than that of another. As it is with individuals, so is it with nations. The Irish, compared to either the English or the Scotch, are, from their physical constitution, a light-hearted, and an improvident people. Their conduct is comparatively but little influenced by a calculation of future consequences. And hence the preventive checks to population, viz., the hope of improving their condition by remaining for a time single, and the fear of making it worse by entering into the state of marriage, have less influence with equal worldly prospects in preventing and delaying marriages in Ireland, than what they have in England or Scotland. And hence, from this cause alone, the average condition of the mass of the people, at the point where the conjoint

influence of the preventive and positive checks render population stationary, is lower in Ireland, than what it is in either of the other two countries.

Again, the average wealth or condition of a nation, is determined by the aggregate produce of land and labour, relative to the population. The larger the former is in reference to the latter, the higher is the average condition of the people. Husbandry, in its present improved state, cannot employ one-half of the population which the produce of the soil, if properly cultivated, is capable of supporting. Hence, in countries merely or chiefly agricultural, such as Poland and Ireland, the population is only half employed; whereas, in countries such as England and Scotland, where agriculture and manufactures are equally prosperous, the population is wholly employed. A half idle population produce little, when compared with an industrious people, aided by the power of machinery. And where little is produced, there is little to divide. Hence, in every old-peopled state, the average condition of the population is higher where manufactures are established, (and the more they are aided by machinery the higher it is,) than in those that are merely, or chiefly agricultural. Though the average condition in relation to food be nearly the same in both, in relation to all the other necessaries and comforts of life, it is very different. Besides, in England, and in free countries generally, where commerce and manufactures are flourishing, the number of those reduced to the ranks of poverty are smaller in proportion to the better classes, than in countries merely or chiefly agricultural, such as Poland and Ireland. The more

numerous gradations in the scale of society in the former, present greater facilities, and excite a more general desire of rising in the world, than in the latter. And as the desire of rising in the world increases like every other, with the facility, and the more immediate prospect of gratification, the preventive checks to population become more efficient, and consequently the standard of subsistence is raised higher, in England than in Ireland.

Finally, Ireland is inhabited by a physically constituted disorderly race of people, and their natural character is rendered more turbulent by bad government, and particularly by the unwise support of an expensive church establishment, the doctrines of which are disliked by nine-tenths of the population. The consequence is, that a considerable proportion of the lands in Ireland, are owned by persons who find it safer, and more comfortable to reside, and spend their incomes in England. The former thus becomes a country that exports a considerable proportion of her produce, in the shape of rent, to be consumed in the latter. And this is another reason why Ireland presents to the eye of the traveller, a general appearance of poverty in comparison with England.

It is unquestionable that poor laws, such as those of England, which confer a legal claim upon the poor when unemployed to demand assistance from the rich, and to have their wages made up to a legal standard when they happen to sink below it, not only open the door to fraud and imposition, but convert the funds destined for the support of the poor into the wages of labour. And it is equally unquestionable, that if

administered in their intentional spirit, by encouraging idleness and improvidence, they would naturally tend to diminish the influence of the preventive checks to population, and spread rather than mitigate the evils they were intended to remedy. But on the other hand, the disposition of a community to protect themselves from the evils occasioned by bad laws, gradually gives rise to correctives in their administration. Thus the dislike to be confined in the parish workhouse, in order to receive relief, has been found in some parts of England, to be a salutary check to the mischief which its laws create. And in like manner, the obligation of each parish to support only its own poor, has formed so strong an inducement to wealthy proprietors to rid themselves of poor tenantry, by destroying their cottages, and preventing them from being domiciliated upon their estates, that the encouragement to population, which the English poor laws have been supposed to produce, has been in some degree balanced, and in some cases more than balanced, particularly in country parishes, by the counteractives to which they have given rise. And while the professed object of the laws has been to relieve and assist the poor, their practical application, by forcing them from the country to seek shelter in the over-crowded, and unwholesome portions of large towns, has often been to distress and destroy them.

Such are some of the causes of the difference in the average condition of the people in England and Ireland, independent of poor laws; and such are some of the reasons, why the English poor laws in their practical operation, have in many cases produced

results in reference to population, totally at variance with the natural tendency of such laws, if administered in their true spirit.

It is a self-evident proposition, that poor laws do not increase the aggregate wealth of a nation; they merely transfer a part of that wealth from the rich to the poor. Such laws benefit one portion of the community at the expense of another. They directly infringe upon the right of private property; and are, abstractly considered, unjust. The circumstance of birth, confers on no man a claim to be supported by the produce of the soil, which is owned, and cultivated by his fellow-creatures. The procreative principle implanted in the human species, is stronger than what is necessary to support a stationary population; and unless restrained by the fear of consequences, would inevitably increase population, till the whole community were reduced to live upon the lowest amount of food capable of supporting life. In like manner, unless the right of private property was respected, all the benefits derived from the social state would be lost; a system of equality would be established; and the whole community would also in this case be soon reduced by procreation, to the lowest possible condition.

Malthus says: " There are two decisive arguments against systems of equality; one is the unsuitableness of a state of equality, both according to experience and theory, to the production of those stimulants to exertion which can alone overcome the natural indolence of man, and prompt him to the proper cultivation of the earth, and the fabrication of those con-

veniences and comforts, which are necessary to his happiness.

"The other is the inevitable and necessary poverty and misery, in which every system of equality must shortly terminate, from the acknowledged tendency of the human race to increase faster than the means of subsistence, unless such increase be prevented by means infinitely more cruel than those which result from the laws of private property, and the moral obligation imposed upon every man by the commands of God and nature, to support his own children." "Man," says Malthus, in another passage, "has only a conditional right to subsistence, and only if he be possessed of property, or if his labour purchase food." If a man prefers present enjoyment, to attempting to insure himself against poverty at a future time, he has no claim upon the property of those who by their industry, good fortune, good management, and economy, have acquired and preserved it. It is unjust that the man who chooses to marry and get a family, before he sees any prospect of providing for them, or perhaps with poverty staring him in the face, should have a legal right to support himself and family at the expense of those who have acted more providently. And it is at least equally unjust, that a man and his family, who have spent and enjoyed the whole produce of their labour in the early, or past portion of their existence, should have a legal claim upon the produce of the industry of the man and his family, who have saved, and laid past a part of theirs, in order to support their respectability, and independence, and enjoy it at a future period of their

lives. Justice requires that the rightful owner should have the free disposal of his property, unincumbered by any legal claim on the part of persons who have never been of any service to him, and with whom he is totally unconnected.

But then it may be said, that human laws have not rigid justice so much for their basis as public advantage, and that the avowed object of poor laws, is to do a slight injustice or evil, that a great benefit may result to society. The objects which poor laws have in view, are :—

1. To endeavour at a trifling expense to the rich, which they can well spare, to raise the condition of the lower orders of society, and secure them from want and starvation, when thrown out of employment during those fluctuations of trade, which it is frequently impossible to foresee or prevent; and which are, and probably always will be, but too little provided for by the lower orders.

2. To equalize the burden according to the means of bearing it; for when the support of the poor is left to private benevolence, some give, and some do not.

3. To do away with public begging, which has a demoralizing and degrading influence upon society. It is farther contended that the cost of maintaining the poor in that way, is greater than by means of a poor tax; and their numbers, even according to Malthusian doctrines, are in consequence thereby more encouraged. Besides, when the poor are left to subsist by begging, their labour is lost to the community, which ought not to be the case under a properly and judiciously administered poor tax.

It is obvious from the preceding statement of the objects which poor laws have in view, that if tolerated at all, their administration would require to be put under severe and strict regulations. In order to prevent the assistance given to the poor having any very pernicious influence in begetting improvident habits, and thereby increasing population, the condition of those who receive aid, should be decidedly worse than that of the lowest class of labourers, who maintain their independence, and live by the fruits of their own industry. In order to prevent fraud and imposition, (and it cannot be altogether prevented otherwise,) those who receive aid should be under the necessity of residing within the parish workhouse. And that their labour might not be lost to the community, they ought to be under the obligation to work according to ability, at any occupation which overseers might direct; and the proceeds of their labour, should be applied to defraying the expenses attending such establishments.

It is evident that by such regulations, the strongest objections to poor laws would be obviated.* But after all it is doubtful, whether, under the best system, and the best administration of poor laws that ever will be devised, the advantages gained are a sufficient compensation for the disadvantages, remote as well as immediate, to which they give birth.

* By the Poor Law Amendment Bill, (for which it is supposed the nation is indebted to Lord Brougham,) the chief defects in the English system of poor laws will be remedied. Even what may be thought the illiberal enactments of that bill, are well calculated to produce the salutary results which they have in view, and which could not be accomplished by any other means.

It is always to be feared that any legal provision for the poor, will, in the estimation of the public, lessen the obligation of a family to support their aged parents; and this of itself, in a social point of view, is calculated in a serious manner to diminish the aggregate happiness of mankind. What a forlorn prospect it would be for a labouring man to be separated from his relatives, and forced to submit to the regulations of a poor's house, in order to obtain the necessaries of life in his old age! And how preferable is that state of society, which necessarily results from the absence of poor laws, where the aged parent is supported by, and resides with the family, which, during the early period of life he has himself clothed, fed, and educated; in whose presence he feels so much happiness; and in whose prosperity and welfare he takes so deep an interest!

Besides, even the best-arranged system of poor laws, is liable to many disadvantages, as well as abuses. It is a tax upon the community, and like all unnecessary or exorbitant taxation, infringes according to its amount, upon the right of every man to enjoy the fruits of his labour, with as little diminution as is consistent with the support of good but cheap government, and the maintenance of order in society. And not to mention the unequal, the vexatious, and arbitrary methods adopted in levying the money for the support of the poor, a considerable amount of it is wasted; and like every other fund raised for a special purpose, is always more or less liable to be misapplied. Thus, a considerable proportion of the money levied goes to support surveyors, assessors,

and others connected with the administration of the poor laws; and other proportions are spent in litigation. In both cases, so much wealth is lost to the community, without the poor receiving any direct benefit therefrom.

Finally, The existence of any legal provision for the poor, however meagre, has more or less influence in counteracting and discouraging prudential habits among a people, which, if no poor laws existed, would show themselves in the more extensive establishment, and more general support of saving banks, friendly societies, and life insurances.

It might be thought that the influence of the preventive checks to population, is restricted exclusively to the lower orders. This, however, is not the fact. "In England," says Malthus, "the preventive check to population operates in a considerable degree. Those among the higher classes, who live principally in towns, often want the inclination to marry, from the facility with which they can indulge themselves in illicit intercourse with the sex. And others are deterred from marrying, by the idea of the expenses they must retrench, and the pleasures of which they must deprive themselves, on the supposition of having a family. The sons of tradesmen and farmers are exhorted not to marry, and generally find it necessary to comply with this advice, till they are settled in business or a farm, which may enable them to support a family. Among clerks in counting-houses, and the competitors for all kinds of mercantile and professional employment, it is probable, that the preventive check to population, prevails more than in any other depart-

ment of society. Perhaps men-servants are under the strongest restraints; for, if they marry, they lose their present employments, and know of no other to betake themselves to."

Under the present system of society, which by every one working for his own individual advantage, is productive of such an immense variety of ranks and degrees of wealth, it might be supposed that poverty must press harder upon the lower orders, according as their numbers relative to those of the better classes become reduced, just as the pressure on the foundation increases with the height of the pyramid, and the narrowness of its base. This, however, is not the case. On the contrary, the preventive checks to population seem to operate more powerfully upon the middle, than upon the lower ranks of society. The labouring classes being at the bottom of the scale already, have no room to sink; and hence they are deterred comparatively in a slight degree from entering into the married state, by the fear of making their condition worse. But while the hope of rising exerts upon the middle classes, at least equal force to what it does upon the labouring population, in preventing and delaying matrimonial engagements, the fear of thereby rendering their condition worse, and of sinking below the rank of their family and acquaintances, operates with fourfold influence.

The condition of the lower orders appears to be actually ameliorated, according as the wealthier classes of society relatively increase in numbers. In proportion as the lower orders relative to the other classes are few in number, so is the opportunity and the

prospect of rising in the world increased, and accordingly the preventive checks to population become more efficient. And it will be found to result therefrom as a general law, that the aggregate condition of the labouring classes in any country, (food, clothing, lodging, and other comforts all included in the estimate,) rises according as their number is few, when compared with the aggregate wealth and amount of the whole population. Besides, in years of scarcity, and in times of commercial difficulty, which are never foreseen, and too little provided for, the accumulation of wealth in the hands of a portion of the community, by affording the means of charity, becomes a blessing to the poor, and some security against starvation.

Emigration, according to Malthusian principles, is merely a temporary expedient, which, as it does not diminish the population permanently relative to the means of subsistence, is not calculated to have any lasting influence in ameliorating the condition of a nation. The power of the reproductive principles implanted in the human species, so far exceeds what is necessary to maintain a stationary population, even in those countries where the average duration of life is the shortest, that any continued systematic plan of emigration, by lessening the efficacy of the preventive checks, would almost proportionally encourage an increase of population, and consequently could have no permanent influence in raising the average condition of a people. On the contrary, emigration, conducted at the public expense, tends to impoverish a nation in two ways. First, the cost of it is defrayed out of the pockets of those who remain. And second, it with-

draws the enterprizing, and those who, from being in the prime and vigour of life, are best fitted for labour, (for such only emigrate,) while it leaves the women and children, and all the unproductive classes, such as clergy and lawyers, and those who, from age and infirmity, are unable to work, and consequently who contribute nothing towards the wealth and productive power of a nation. Public liberty requires, that every individual should possess the privilege of emigrating without hinderance to wheresoever he chooses, provided he does so at his own expense. But the means of emigration should never be supplied from the public purse, except perhaps when large bodies of workmen, concentrated in particular districts, are suddenly thrown out of employment by improvements in machinery, or by unforeseen political or commercial vicissitudes. And even in such cases, its propriety is questionable. Workmen thrown out of employment soon find out other means of supporting themselves; and before any plan of emigration can be arranged and carried into effect; and even before such an expedient is thought of, the evil which suggested it, has usually in a great measure subsided.

Upon this subject it may be farther remarked, that to prevent disputes between nations arising from the misconduct of emigrants and persons abroad, every man ought to be subject to the laws of the country in which he happens to be, and to them alone; nor should the parent state have any right to interfere in his behalf.

Infanticide, according to Malthus, has no influence in keeping down population, so as to raise their aver-

age condition. In fact it appears to have a contrary tendency. Owing to the protection afforded by feelings of parental affection, the number of children destroyed where infanticide is allowed, does not compensate for the additional number born, in consequence of the preventive checks to population being thereby in a considerable degree removed. It is accordingly found, that in countries, such as China, where this barbarous custom is permitted, population presses harder upon the means of subsistence, and the condition of the people is more wretched, and the shortening of life occasioned by poverty greater, than in those where it is not. Hence it is consistent not only with moral propriety, but also with political expediency, that infanticide is prohibited amongst all civilized nations.

It is a popular, though in my opinion an erroneous belief, that the condition of mankind would be ameliorated, by supplying them with education, and religious instruction, at the public expense. That the former should be accomplished by taxing the community, or burdening the land, for the support of a national system of education, and endowed schools; and the latter, by making similar provision for supporting an established religion, and endowed churches.

National systems of education supported at the public expense, are but systems of equality so far as education is concerned. It is the duty of every man to educate his family at his own expense; and in so doing, he not only receives remuneration in proportion to the interest he takes in promoting their future welfare, but he gains a prospective advantage in being

more likely to obtain assistance from them, if disease, or misfortune, should in his old age, render it necessary. The expense of educating a family, is one of the circumstances which deteriorate a man's condition in the married state; and consequently is one of the items which have an influence in preventing and delaying marriages, and in diminishing the pressure of population upon the means of subsistence. Besides, it is not just that the man who has no family, should be taxed for the education of those with whom he is unconnected, and from whom he never received, nor expects to receive any benefit.

A national system of education is liable to other disadvantages. It begets a system of patronage and corruption in the appointment of teachers; it increases the expense of education to the community; by establishing one uniform system it prevents all improvement both in the art of teaching, and in the course of study; and deprives the nation of the benefit which they would derive from the ingenuity, and industry of teachers, competing individually for public favour.

The right of appointing teachers to national, and endowed schools in general, must always be vested in some patron, or patrons. And for every living, the emoluments of which are higher than the wages obtained by a common workman, there always will be more than the requisite number of applicants. This gives rise to an endless system of canvassing, and various ways of exercising influence. From the impossibility of patrons serving every applicant, much ill-will and opposition throughout society is excited;

and teachers are frequently selected more in consequence of influence exerted in their favour, than for any merit which they themselves possess. All these evils are avoided by having no national system of education, no endowed schools, and no patrons but the public, for whose favour teachers ought to be allowed freely to compete with each other upon equal terms; and be remunerated for their individual exertions, and public usefulness, exclusively by those who employ them.

That a national and endowed system of education would be more expensive to the community, than one of free competition among teachers, may be inferred from the fact, that all government, as well as endowed and chartered establishments, are uniformly conducted with less economy, and with less advantage to the public, than those which are set up for private benefit upon principles of free competition. And the best proof of this being the case is, that whenever the trade is opened to the free competition of private individuals, the trade of the government or chartered company falls to the ground. Besides, monopolies, and chartered companies with exclusive trading privileges, are ever observed to arrest improvement and ingenuity in conducting mercantile affairs; and become means whereby the articles they supply are raised exorbitantly in price to the consumer.

Again, seminaries established by law, are ever apt to be erected in unsuitable localities for educating the community at a cheap rate. The caprice, or the private interest of a patron, or influential person, who has ground to feu, may determine the site of the law-

established school, without regard to the accommodation of those who are to be educated. And it may be here observed, that endowed seminaries, and charity schools founded upon the bequests of benevolent persons, are usually so inconveniently situated, that they exhibit remarkable examples of the misapplication of the wealth and resources of a nation; and instead of affording cheap education to the poor, they merely create sinecure births for lazy teachers. In proof of these opinions we find nineteen munificently endowed colleges at Oxford, the population of which is less than 20,000. And in many rural districts, such as at Dollar in Scotland, where there is a very limited population to educate, we find an extensively endowed seminary, the patronage of which is intrusted exclusively to the minister and elders of the parish. What would be thought of the policy of a law, requiring that the whole produce of the soil, and the manufactures of England, should be sent to Oxford and Cambridge for sale? And yet it would not be more absurd, than that the youths of England should require, at an extravagant expense, to be sent to Oxford or Cambridge, in order to receive a college education.

Again, the course of study in endowed schools, is frequently any thing but what is useful to the pupils in after life. Thus we find that one-half of the time devoted for education by the present system, is spent in studying the dead languages, Latin and Greek,* a knowledge of which, since they ceased to be spoken,

* At Glasgow, the study of Latin occupies six years; four years in the High-school, and two in the college.

and since all the works of any value in these languages have been translated, is actually of no use to mankind.

But endowed schools, and such as are patronised by magistrates and other municipal rulers, besides perpetuating absurd courses of study, actually increase the expense of education, and smother competition. And instead of fostering education, have practically the effect of counteracting and retarding it. Thus in Glasgow, what is called the High-school, is patronised, and the teachers are appointed, by the magistrates and council. A pension of £50 a-year to each of the teachers, numerous premiums annually given to the most deserving of the pupils, and school accommodation, are all provided at the expense of the town's funds. In this school, boys are taught Latin for four years upon such a wretched principle, that at the end of that time, they are unable to speak or write the language; and are even incapable of translating a sentence out of a common Latin author, without the aid of a dictionary; while in the same time, and with as little labour if properly directed, they might master half a dozen of the living languages.

It might be supposed that endowing teachers out of the public purse, would have a proportional effect in reducing the fees exacted from the pupils. This, however, is seldom or never the case. In fact, it is generally the reverse. The fees in the High-school above noticed, are 12*s*. 6*d*. for a quarter of a year's instruction,—six weeks of a vacation annually being charged at the same rate. It might be thought that such high fees, would give rise to opposing schools, supported upon independent principles by teachers

themselves. But such is the baneful influence of the patronage of local authorities, that the patronised school becomes the fashionable one ; and is thereby so much raised in public estimation, that it crushes, and altogether prevents competition.*

In like manner, granting to certain colleges, the exclusive privilege of conferring licenses to practice surgery and medicine, upon the production of tickets certifying that a previous attendance of the prescribed classes in these endowed colleges has been complied with ; and also conferring upon such institutions, the exclusive right of granting degrees, the possession of which confers a higher rank, in respect to professional knowledge, in the estimation of the public, destroys all free competition in teaching. In consequence of the monopoly thereby created, professors are enabled to exact exorbitant fees from the students, in addition to the annual income arising from college property and grants from government, which is also divided among the professors. Thus, in the college of Glasgow, a fee of three guineas is exacted from each

* Those who call themselves the Reformed Town Council, (by way it is supposed of increasing their patronage,) have recently appointed similarly endowed teachers, in other branches of education, to this High-school. In reality, it is only the families of the better classes of citizens, that can afford to receive instruction at this seminary. And as the town's funds, which are intrusted by law to the management of the town council, equally belong to all citizens, the taking a portion of them to endow additional teachers in this school, besides being a gross act of injustice to teachers who compete for public favour upon independent principles, is neither more nor less than robbing the poor, in order to teach the families of the rich.

student for two hours' instruction a-day, during six months, in a numerously attended class; when as good instruction, provided no endowed colleges existed, would be afforded the public by the free competition of teachers, for one-fifth, or possibly one-tenth part of that sum.

That all should be educated is not of such essential importance to the happiness of society; nor are the advantages of education so much overlooked, as to require that this commodity should be exclusively provided for by law and taxation. Education becomes of less value to each individual, according as the number educated is greater. And reasoning from the acknowledged influence of free trade, in determining the proper supply, and the true value, of every other useful commodity, it may be inferred, that if education were neither restrained, nor encouraged by law, but left to free competition among teachers acting individually for their own advantage, it would be supplied at the cheapest rate, and to the extent that is most useful to the community at large. In the present state of society, the supply of education, like that of every other commodity, may safely be left to be regulated by the demand. And free trade in teaching, as in every other department of merchandise, is that which invariably furnishes the best article at the cheapest price.

If no endowed colleges or seminaries existed, we should find schools erected, (just like shops for the sale of commodities,) in the most convenient localities for supplying education to the public. And instead of indolent, careless, overpaid teachers, which

the system of patronage, endowments, and appointments for life create; we should have industrious, careful teachers, freely competing with each other for public favour, and remunerated according to their respective degrees of usefulness. And, instead of slow methods of communicating instruction, and absurd courses of study being perpetuated; the public, acting upon the mercantile principle, of purchasing the best article at the cheapest price, would soon be found to patronise only such teachers as were most useful in accelerating education, and in communicating the greatest amount of valuable information in a given time. Under such a system of free competition, instead of education being confined within the walls of endowed and misplaced seminaries, (where the fees, and the courses of study are seldom or never altered, except disadvantageously, so far as the public interest is concerned,) it would be brought to every man's door. And teachers, who are ever the best judges of each other's merit, and whose mutual interest creates the strongest stimulant to mutual exertion and confidence, would be found combining with each other, with a view to afford valuable courses of instruction. And where the poverty of certain districts rendered cheapness of essential importance, the same room or hall, would be found as well fitted for giving instruction in every department of science, as separate halls for each department. Under such a free trade system, the teaching of dead languages, for want of pupils, would soon cease; and courses of study, in exact proportion as they were found

useful in after life, would be patronised by, and supplied to the public.*

To tax the community, or burden the land, in order to endow churches, and support an established

* Notwithstanding the obvious nature of the observations in the text above, Lord Brougham has recently proposed a series of resolutions in the House of Lords, explanatory of his views relative to the establishment of a national system of education. In his speech introductory to the resolutions, he shows how apt funds bequeathed for charitable purposes, are to be wasted and misapplied; and how inefficacious bequests for educating the poor, have usually been for accomplishing the objects which the testators had in view. "I would just refer," says Lord Brougham, "to a few instances, in order to show what large sums of money were squandered much worse than uselessly, in the distribution of the funds of several endowed schools. The funds for endowed schools in Middlesex, were, in 1819, £31,000 a-year, and the number of children educated at them did not exceed 2,260. The funds for a similar purpose in London, amounted to £84,000 a-year, and the number of children was not more than 1,630. In St Paul's, (a day school,) the regular charge for each pupil was from £15 to £20, besides other items, which made it amount to a larger sum." In June, 1835, Mr D. W. Harvey made a motion in the House of Commons, for the appointment of a select committee to inquire into the state of the public charities in England and Wales. He stated "that a previous commission, appointed for a similar purpose, had produced twenty-four reports, averaging each 800 pages, without any beneficial consequence resulting." He farther mentioned, "that by returns of the money which had been actually advanced by the Treasury, it appeared that the expense of that commission had not been less than £210,000; and taking the printing, &c. into account, it might be said, in round numbers, that the commission had cost the country £250,000." He adds: "So great was the mismanagement, and, above all, the profligate plunder of the property belonging to the poor, as testified in these reports, that it presented a monument of the incapacity of our

religion, is at least as objectionable and impolitic, as it is to tax the community for the support of a national system of education; and the objections to the one, are in general applicable to the other. Religion

courts to do them justice." The information communicated in the speeches of Lord Brougham and Mr D. W. Harvey demonstrates, that property set aside, or bequeathed for any special purpose, has a natural tendency to beget corrupt patronage, fraud, and plunder, in its application. When this circumstance is considered, in conjunction with the trouble and expense of collecting school-rates; and of supporting commissions for looking after the funds, keeping teachers at their duty, and preventing the patronage created from becoming a political engine for party purposes, (which are all avoided and rendered unnecessary by the free trade plan;) it may be inferred, that the establishment of a national system of education, and the endowment of schools in general, besides producing other evils, would saddle the country with a source of political discord, and a load of unnecessary taxation. And there is little doubt, but that it would ultimately tend to impoverish the nation, by causing education to absorb a much larger proportion of the produce of land and labour, than it would do if left to voluntary teachers, competing freely with each other, and acting severally for their own individual advantage.

Lord Brougham admits that the education of the people by means of unendowed schools, is rapidly extending; and he speaks as if he thought, that the voluntary schools set up merely for private advantage, and which have already done so much for education, should not be inconsiderately interfered with. Notwithstanding, in his national system, he goes the length of proposing, that what he calls Normal schools for teaching teachers, should be supported at the public expense; and of course, that additional taxation in some form or other should be imposed for that purpose. The art of teaching is not more difficult to learn, than that of other trades for the supply of the necessaries and luxuries of life. It is likewise equally susceptible of improvement. But improvement in the art of teaching is certainly more likely to go on under a free

is a matter between God and man, with which human laws, having for their object the security of personal rights and property, have nothing to do whatever. Mankind are at the expense of supporting governments for the purpose, not of deteriorating, but of ameliorating their condition; for the purpose, not of diminishing their natural rights, which entitle each individual to pursue his own happiness according as his reason directs, so long as he does not encroach upon the rights of his neighbour, but in order that those natural privileges may be better secured. Every man has by nature the right of examining the evidence upon which any religion is founded; and of expressing his opinion thereupon, either in speech or writ-

system, which permits teachers to exercise their own judgment and ingenuity in the matter; and where, from increased public patronage, they may expect to be remunerated for their ingenuity and skill; than under a national system of education, which supposes the adherence to one uniform plan, and gives no encouragement to ingenuity and attentive zeal on the part of teachers. To provide proper food, clothing, and house accommodation, is of infinitely greater importance to the comfort and happiness of mankind, than to provide education. But what would be thought of a proposal to establish schools at the public expense, for teaching farmers to cultivate the soil; others for teaching bakers to bake bread; and others for teaching brewers to make malt liquors? And what would be thought of a proposal to tax the community for the support of schools, to teach manufacturers to make cloths of different descriptions; and tailors and milliners, how to fashion them into suitable habiliments for human beings to wear? Or what would Lord Brougham think of a proposal to tax the community, or burden the land, for the support of schools to teach clergymen sound doctrine; and, which in the opinion of many is paramount to all other considerations, the proper method of communicating religious instruction to the people?

ing. And every man has also the right of worshipping his Creator, according to the form which he thinks most acceptable. The existence of an established church supported at the public expense, is at variance with these rights. To tax a man for the support of a religion in which he does not believe, is a gross act of injustice; and to tax one sect of Christians for the support of a particular form of worship from which they dissent, is equally unjust. Church property, as well as all public property, belongs equally to all members of the community; and any partial application of such property for the benefit of a particular class of the community, is an act of injustice towards all the other classes. In short, it would not be more unfair to build the dwelling-houses of only one sect at the public expense, than it is to build, or endow the churches of only one sect at the public expense.

Nor is the majority of a community, or the government acting by their authority, entitled to tax a dissenting minority to support an established church. They have a right to enforce universal submission only to such laws, as would be rendered nugatory, if a dissenting minority were permitted to resist. But no majority of a community are entitled to force universal compliance with laws, where the preservation of their rights, does not require such compliance. It is obvious that the majority of a community, or the government appointed by them, are entitled to force universal compliance with criminal laws; for if a dissenting minority were allowed to violate them with impunity, the rights of the majority, by whose author-

ity such laws were made, could not be thereby protected. It is different however with the religious rights of mankind. In this particular, the natural rights of all may be perfectly maintained, without the compliance of one party with the will of another. Both the majority and the minority can enjoy their respective religions, and practise their own forms of worship, without in the least degree invading the rights of each other. And therefore, in accordance with the equitable principle of every man paying only for what he himself uses, or gains some advantage from, no majority of the community however great, nor any government acting by their authority, have a right directly or indirectly to tax any minority however small, for the support of any church or form of worship, from which they dissent.

One of the arguments advanced by the advocates of church establishments, is, that an established church acts like a cheap police in maintaining order in society. Such an ill-founded argument hardly deserves an answer. Religion supported upon equitable voluntary principles, always contributes to maintain order. But law-established religion, besides being inimical to public liberty, has frequently been a cause of wars and massacres, and of every degree of persecution and intolerance. Even at present in our own country, where the liberality and good sense of the mass of the people enforce toleration, (for it unfortunately appears to be the fact, that clergy as a body, are always more or less disposed to be intolerant if they have the power,) law-established religion, which supposes the injustice of taxing the whole, for the

benefit of only a portion of the community, creates, and ever will create, discord and animosity throughout society. And the established church of Ireland, instead of being a cheap substitute for a police, is not only a most expensive burden itself, but renders a strong police, and the presence of a standing army absolutely necessary, in order to keep down the tendency to tumult and insurrection, which its existence creates.

Another argument in favour of church establishments, is, that their existence is necessary for the support of religion. Those who advance this opinion may be reminded, that Christianity originally took root, and spread, without being supported by law, or established churches. In the United States of America, religion flourishes without the assistance of a church establishment, and seems to exert a salutary influence upon the moral happiness of mankind, totally free from every disadvantage. This is the natural result of religion left to grow, and spread of itself, without the aid of government, and church establishments. In that country, where a nation is presented rising to wealth and greatness, with a rapidity unexampled in ancient or modern history, the Protestant and the Catholic, and all other sectarians, live in perfect harmony with each other. It is because there is no established religion, and no favoured sect. There the law recognises no man in his religious capacity; and each sect, at their own expense, build and support their own churches; and without molestation enjoy their own religion, and practise their own form of worship, without being

taxed directly or indirectly for the support of any other.*

To man, but to none of the inferior races of animals, is the foreknowledge given, that existence in this world must soon terminate. But man revolts at the prospect of annihilation, and desires to perpetuate his existence. This desire, co-operating with the prospect of mortality, has gained a ready and willing belief, for all the various religions that have appeared on earth; and which severally hold out the prospect of eternal life and happiness, upon conditions favourable to morality. And such is the influence of preconceived opinions, and such the prejudice in favour of believing, and practising, that which we have been accustomed without examination to consider true, and

* It is worthy of being remarked, that though the population of the United States be composed of persons, or the descendants of persons, originally professing all different religions, and belonging to every different sect; the different creeds and forms of worship of the mass of the people, are gradually assimilating to the Presbyterian form established in Scotland, with the difference of being unconnected with the state, and freed from patronage. From a recent survey it also appears, that in Ireland, the Presbyterians, who, in that country, are a dissenting body, are increasing in a much more rapid ratio than the Catholics; while the number of Episcopalians, notwithstanding their being supported by an enormously endowed church establishment, seems to remain almost stationary. From these facts it may be inferred, that the Presbyterian form of Christianity, on account perhaps of its being the simplest, and cheapest of all religious forms of worship; and likewise from its being the freest from superstitious reverence, and empty mummery, is that which would spread itself over Great Britain and Ireland, were it not for the existence of endowed church establishments.

best, that the religion of the mass of the people, in every age and nation, is the same as that of their forefathers. Our religious faith is therefore in a great measure determined by the place of our nativity, a circumstance over which we have no control. Having been born and brought up in Britain, a Christian country, we are Christians. But had we been born in Turkey, we would have been followers of Mahomet.

Birth and education determine not only the particular religion which we profess, but even, though not so certainly, the peculiar sect with which we ever afterwards remain connected. Thus, the mass of those who are born and brought up among Catholics, remain Catholics; and those who are born and brought up among Protestants, remain Protestants. In like manner, those who are born and brought up, whether among Methodists, Quakers, Seceders, Presbyterians, or Episcopalians, for the most part remain ever afterwards, attached to the faith, and form of worship in which they have been bred.

These facts ought to teach us to exercise unlimited toleration, towards those who differ from us in religious belief; and show how presumptuous it is in us to declare the religion of our neighbour untrue, or his form of worship unacceptable to his Creator, because ours happens to be different. Had our birth and education been the same as that of our neighbour, and our neighbour's the same as ours, the creeds which we severally and exclusively believe, and the forms of worship to which we are severally attached, would have been reversed. No man is responsible for the

belief, or form of worship of another; and therefore, no man is entitled to use coercive measures, in order to make his own practice in these particulars, a rule for others. While we severally maintain the right of exercising our own judgment upon religious subjects, and of practising any form of worship which we approve; let us at the same time be sure, that in thought, word, and deed, we grant to our neighbour, the same right which we claim for ourselves; and thus obey the greatest of all moral precepts, " Do unto others as you wish to be done by." If governments would merely confine themselves to protecting all sects in the exercise of their own peculiar forms of worship, and prevent one from encroaching on the rights of another, we may rest assured, that religion will serve all the wise and benevolent purposes for which its introduction on earth was intended. And no sincere Christian will ever believe that those principles in human nature, which, without almost any thing approaching to evidence, have gained credit for the grossest and most improbable superstitious notions that human ingenuity could devise, are not sufficiently powerful to perpetuate the religious faith in which he believes.

Besides the injustice of church establishments, and the ill-will and disturbance in society which their existence creates, they are objectionable in consequence of being more expensive than voluntary churches, relative to the amount of religious instruction which they afford; and hence, by absorbing an unnecessarily large proportion of the resources of a nation, they tend to lower the average condition of the people.

In Ireland, we have a remarkable instance of the wasteful expenditure of the public money, in supporting an established church. About £3,000,000 annually are set aside for the support of this useless establishment, while, by the recent report of the commissioners to parliament, the number of Episcopalians, including men, women, and children, therefrom receiving religious instruction, is only 853,000. Nor is it any answer to this objection, that a large proportion of the funds for supporting church establishments, consists partly of property bequeathed in perpetuity by religious persons; and partly of a portion of the rent of land, called tithes, set aside by law in ancient times for that purpose, and which now has no proper owner but the church. The wealth of a community consists of the produce of land and labour; and its sum total in any given country, without deviating far from the truth, may be valued at a certain annual amount. Now, if a larger proportion of this produce of land and labour be permanently set aside in order to support a church establishment, than what would provide an equal amount of religious instruction, to the same portion of the population by means of voluntary churches, the community are to that extent impoverished. The larger the proportion of the produce of land and labour annually set aside for the support of religion is, the smaller must be the proportions set aside for supplying the other wants of mankind.

Discontent never results from permitting every individual to act according to his own will, so long as he does not encroach upon the rights of others. And

general contentment is more likely to result from laws and institutions, which allow every man to spend his income how and where he chooses, and with as little diminution in the form of taxation as possible; than from such as deprive him of what he considers an unnecessarily large proportion of his income in the shape of taxes, and especially if the revenue therefrom accruing be applied partly, or principally, to purposes from which he receives no gratification, and derives no benefit. The public are ever the best judges of their own wants, and if left to themselves, will make provision for them upon the principle, both with respect to cost and quality, which is most satisfactory to themselves. Now, religious instruction, and places adapted for worship, are desires which the public wish to gratify. And, as the tastes and notions of individuals vary with regard to the value of the various necessaries, luxuries, and enjoyments of life; so do they vary with regard to the value of church accommodation, and the kind of religious instruction. Each individual has a natural right to spend his income according to his own taste. And hence, it would not be a more unjust and impolitic infringement upon the natural privileges of mankind, nor a more tyrannical and uncalled for usurpation of the individual rights of a people, for government to determine what proportion of income each man should set aside for purchasing the different kinds of food and clothing; and what other proportions, for travelling expenses, house accommodation, and medical attendance; than it is for government to determine what proportion of the income of individuals, or, (which is a concealed

method of doing the same thing,) to determine what proportion of the aggregate income of the community, should be set aside for the purpose of providing either education, or religious instruction to the people.

The right of entailing lands, or of bequeathing property in perpetuity, whether for the purpose of endowing churches or seminaries, or supporting charitable institutions, besides being disadvantageous in various other respects, tends to lower the average condition of the community. Every man should have the fullest right of giving away his property during his life, or of bequeathing it at his death, to whomsoever he chooses. But to fix the application of property in all time coming, is an infringement upon the rights of posterity. If all the lands in the country were entailed, and these entails could not be broken, the whole population, with the exception of the heirs to such entails, would be thereby deprived of all right to hold property in land. Now as the land constitutes a large proportion of the whole property in the country; and as individual wealth consists in being possessed of a portion of the property in the country; the difficulty of acquiring wealth, or even of gaining more than an average livelihood, by means of industry, economy, and good management, increases, according as the proportion of land and other property held in entail, becomes greater. In like manner, the greater the amount of property bequeathed in perpetuity, or set aside by law, for the support of churches, schools, or charitable institutions, the less can be held by, and be at the disposal of private individuals, and of course the greater is the difficulty of

acquiring wealth, or of gaining more than an average livelihood, by the exercise of economy, and well-directed industry.

It has been already stated, that the desire of rising in the world increases, like every other, with the facility and the more immediate prospect of gratification. Hence whatever diminishes a man's chance of rising in the world, whether it be entails, bequests in perpetuity, heavy taxation, or any other cause, is unfavourable to the exercise of prudential habits in contracting marriages, and therefore tends to deteriorate the average condition of a people.

Abstractly considered, there is something ridiculous in the existence of hereditary owners of land, who, as if they were fatuous persons, are deprived of the right of selling, or otherwise disposing of their property. And as neither virtue, wisdom, nor the possession of knowledge, are hereditary, to defend the right of entailing property, upon the principle, that it is necessary in order to support a hereditary peerage, and a hereditary legislative body, is something like saying, that one absurdity requires to be supported in order to perpetuate another. When it is considered that a large proportion of the hereditary peerage, and other owners of entailed estates, notwithstanding their immense annual revenues, are deep in debt; and that it is chiefly through their influence, and for the purpose of providing for the junior branches of their families, that the country continues to be burdened with expensive church, and military, and naval establishments, the absurdity of permitting entails and their natural concomitants to exist, becomes apparent.

An elective peerage kept up to a certain fixed number, and appointed by the king with the consent of his ministers, and liable to be denuded of nobility only upon ceasing to be able to pay their debts, is in theory, and would be found in practice, greatly superior as a legislative body, to one that is hereditary. Such a nobility might be expected to set a good example to their inferiors in rank; and none of those unseemly spectacles, which the present state of the law produces, viz., noblemen with immense incomes running into debt, and in the character of legally protected swindlers defrauding honest tradesmen of payment of their accounts, would be presented. The natural rights of every generation are the same; and no laws ought to be allowed to exist, which in the slightest degree infringe upon the rights of posterity. Laws and institutions which afford the greatest facility to the acquirement of wealth and property, not only encourage the exercise of prudential habits in contracting marriages, but by promoting industry and economy, increase both the aggregate, and the average individual wealth of a nation. In order that each individual should possess his just right of acquiring wealth, and of being fully recompensed for his industry and ingenuity, it is necessary that every one should possess the uncontrolled privilege of spending his property, and that no right of entailing or bequeathing property in perpetuity should be permitted. If such were the case, the ultimate consequence would be, that the middle classes of society, which are both the happiest, and the most moral portion of the population, would be greatly increased in numbers; and

property would never accumulate in the hands of single individuals to such a monstrous extent, nor be so apt to get into the possession of unworthy persons, as under the present laws. Upon this point I will only add, that instead of being an injury, I conceive it would be a public benefit, not only that the right of entailing property should cease, but that all property bequeathed in perpetuity, as well as all church property upon the death of incumbents, and which of course belongs to no living individual, should be sequestrated, and applied to defray the expenses of government.

Unnecessarily heavy taxation, whereby the people are robbed of a portion of their income, is another means by which the difficulty of acquiring wealth, or of gaining more than an average livelihood is increased; and which, by discouraging the exercise of prudential habits, deteriorates the average condition of society. It is the natural right of every man to enjoy the fruits of his industry, with the least possible diminution in the shape of taxation, consistent with the support of good government, and an effective administration of the laws. Hence, that form of government, and that code of laws, are the best, which at the least expense, afford the greatest security to persons and property.*

* Representative forms of government, the members of which are elected by ballot, with publicity given to all their procedure, afford the best practical security, that economical management will be adhered to, and that the public money will not be misapplied. In addition, however, to these precautions, it is advisable, that those who have charge of the public funds and the patronage

National debts, which render heavy taxation necessary in order to pay the interest of them, are palpable infringements upon the rights of posterity. Borrowing money and converting it into a transferable stock, bearing interest, and using it for government purposes, is neither more nor less, than one generation borrowing and spending money, and leaving those that succeed to pay the interest thereof, or the principal, according as they find it convenient. The reason assigned in defence of this conduct immediately subsequent to the Revolution in 1688, when the debt of Great Britain commenced, was, that the wars arising out of the Revolution were carried on as much for the benefit of succeeding generations, as for that which then existed; and it was therefore supposed to be fair, that succeeding generations should pay part of the expense. A similar argument can be brought forward in defence of contracting debt during every war. Succeeding generations may be supposed to be benefited by their ancestors resisting aggression and invasion. All such arguments, however, are evidently absurd and unjust. Are succeeding generations to be burdened and incapacitated from defending themselves by being encumbered with the debts of their ancestors? Is the industry of their labour to be thus mortgaged? Or are they bound, upon any

in burghs, should not be permitted to remain too long in office,—a circumstance which is uniformly observed to have a corrupting influence. This is best provided against by a burgh constitution, which prohibits town-councillors from being elected to serve for more than three years at a time; and, upon going out of office in rotation, from being eligible for at least a corresponding period.

principle of justice, to pay the taxes and war expenses of previous generations as well as their own? Certainly not. The natural rights of every generation are the same; and in order thereto, each generation ought to be as unincumbered with debt as that which preceded it. The son is not bound for the debts of his father, or of his grandfather, when they happen to die without leaving property to pay their debts; and yet he might have been benefited by some speculation of theirs, had it succeeded. If the descendants were responsible for the debts of their ancestors, the produce of our labour might not have belonged to us. And a profligate parent, instead of supporting his family, might live at their expense before they were born. Upon the same principle, the government expenses of one generation might be thrown upon the next. No taxes might be raised at all. One loan after another might be contracted for, to pay the interest of what had been previously borrowed, and to defray all the current expenses of government.

From these observations, it is evidently a settled point, that can stand neither examination nor discussion, that a nation is under no obligation whatever, except as a matter of expediency, to pay either the principal, or the interest of debt, contracted before their time. The only principle upon which governments have any right, on a pressing emergency, (such as the unexpected breaking out of war,) to contract debt, is that of annuities terminable in thirty, or at most in forty years, which would throw the burden of payment, upon what may be called the generation that contracted it.

As the sudden cancelling of the national debt would occasion almost universal bankruptcy, and much individual suffering, chiefly among the mercantile classes, who had very little to say in its contraction; it might be expedient, that individual holders of stock should be paid in full. But all stock held by corporations, and other public bodies, and all investments in stock for the support of public institutions, (the sum total of which is supposed to include three-fourths of the debt,) should be immediately cancelled. And if any private property is to be made available for the payment of the portion of the debt held by private individuals, it ought certainly to be the entailed estates of the nobility upon the demise of present incumbents, and of those whose ancestors had a share in the management of national affairs, during the period when the debt was contracted.*

* It has been suggested, and in all probability correctly, that if government were to pass an act, declaratory of the illegality of contracting for future loans, on any other principle than that of terminable annuities; and were at the same time to impose taxes, estimated to raise an annual revenue of £5,000,000, to be applied exclusively and inviolably in all time coming to the liquidation of the national debt; the additional security thereby given to funded property, and the amount of capital thereby thrown into the market, would, in the course of two years, so lower the common rate of interest, and, in particular, the rate at which government could borrow, that the whole of the three per cent. consols might be converted into a stock bearing interest of two per cent. This, in reality, would reduce the interest of the debt nine millions annually, viz., from £27,000,000 to £18,000,000. It is obvious that the adoption of such a measure would cause stocks to rise rapidly. And it is certainly proper that the country, and not the fundholders, should get the benefit thereof. If, therefore, such a mea-

As the population in any country is regulated, much more by the amount of food which the wages of the mass of the people can command, than by the amount of the other necessaries and luxuries of life, every improvement in machinery, by which the amount of manufactures with the same labour is increased, and by which their price relative to that of food is reduced, augments the aggregate wealth of the nation, and raises the average condition of the people. Though improvements in machinery may, for a time, deteriorate the condition of the labourers thereby thrown out of employment, even their condition, so soon as they have got into other avocations, is improved as much as that of the other members of the community. While the average condition of a people in reference to the quantity of food they can severally command, remains unchanged by improvements in machinery; in relation to the amount of the other necessaries and luxuries of life thereby reduced in price, it is ameliorated. Hence the reason, that the average condition of a labouring man in a civilized country, where human industry and manufacturing skill are assisted by machinery, is superior to that of a chief of a savage tribe. The former by means of his wages can command as much food as the latter; and a much greater amount of all the other comforts, conveniences, and luxuries of life.

In like manner, by assimilating and adopting de-

sure were adopted, it ought to be simultaneously enacted, that government should be entitled to pay off the debt at the price of stocks on the day on which the measure was first proposed in parliament.

cimal divisions as far as possible for weights, measures, and coins, throughout the kingdom; and even by extending the assimilation, by arrangements for that purpose with the governments of other countries, with which we carry on commercial intercourse; the labour of supplying ourselves with the necessaries and luxuries of life, whether produced at home or abroad, would be diminished. Hence the wealth of the nation would be thereby increased, and the average condition of the people raised, just as it is by improvements in machinery.

Upon similar principles, every improvement in our civil institutions, whereby a smaller number of persons can perform all the work, in any particular department, that is required, operates like improvements in machinery, in increasing the amount of useful articles produced relative to the population; and accordingly raises the average condition of a people. Thus by arranging, simplifying, and improving our code of laws, and by assimilating them throughout the kingdom, instead of having different laws, and different sets of law-functionaries for England, Scotland, and Ireland, a smaller number of lawyers would suffice for all the business required of them. In like manner, passports, and alien laws, which place foreigners on a different footing from natives, should be for ever abolished; and Britain ought to set the example to other countries. Such institutions and regulations, are but relics of ignorance and despotism. They give rise to fees and perquisites, which support a class of persons, whose business, instead of being of any use to mankind, merely obstructs commercial intercourse,

and occasions unnecessary expense, trouble, and waste of time to travellers. Of course, the superfluous hands thrown idle by such and similar reformations, in order to support themselves, would have to direct their attention to the production of articles useful to mankind. Hence the average condition of the people would be raised, by a greater amount of useful articles, relative to the population, being thereby produced; and which, in reference to the price of food, would be sold, or divided amongst them at a lower rate.

In like manner, war, independent of the additional taxation necessary for its support, deteriorates the average condition of a people, according as it withdraws a greater or less proportion of the labouring classes from productive avocations, to such as yield nothing useful to mankind. When it first breaks out, a demand for labourers, which raises the price of labour, and of all articles thereby produced, takes place. But though the condition of the labouring classes, as well as that of those who hold stocks of manufactured goods thereby raised in price, may at first be apparently improved, this effect is merely temporary; and results only when the war happens to be with a nation with whom we carry on so little trade, that the number of labourers thrown idle by the suspension of commercial intercourse with them, is less than those that receive employment in avocations connected with the support of war. Though the trade of certain places, and the condition of certain classes of artificers, may during its continuance be somewhat improved; the trade of other places, and of other classes of labourers, is more than proportionally injured. Upon

the whole, its effects are decidedly prejudicial. It diminishes the aggregate production of useful articles relative to the population; and in proportion as it does so, it lessens their aggregate wealth, and deteriorates their average condition.

Peace, on the other hand, independent of the benefit resulting from the reduction of taxation which it permits, is favourable to national wealth, and individual prosperity. The transition from a state of war to that of peace, operates much in the same manner as improvements in machinery. The number of labourers thereby turned from the unproductive avocations of war, to the productive departments of manufacturing industry, lowers wages, and the price of all manufactured goods. But though the condition of the labouring classes, and of those who hold stocks of manufactured goods, may at first be thereby injured; still as its effect is to increase the aggregate production of useful articles, relative to the population, it ultimately increases the aggregate wealth, and raises the average condition of a people.

Discriminating duties upon foreign articles, according as they are imported in foreign or British ships, is a contemptible device for favouring the home shipping interest, which foreign governments can easily see through, and easily counteract. The result of such a selfish policy when met by counteractives, is, that vessels can only get a cargo in one direction: they sail to foreign ports empty, with the chance of getting a cargo home. This, by requiring a greater number of seamen, and of ships, to do the same amount of work, increases the freight; and conse-

quently injures the condition of both nations, by raising the prices of the articles which they severally import. For the benefit of all nations who carry on commercial intercourse with each other, a reciprocal understanding should exist, that all ships, with their cargoes, should be permitted to enter ports, and to load and unload, on a footing of perfect equality, without regard to where they were built, or where their owners reside, or whether navigated by natives or foreigners.

As free competition is that which invariably produces the best article at the cheapest price, monopolies, and exclusive trading privileges of every kind, should be abolished. Our tastes are different; and each individual is the proper judge of what he wishes to purchase for his own use. Of course, when two articles are offered for sale at the same price, a man's condition is certainly better, (and a similar remark is applicable to the condition of a nation,) when he is permitted to purchase the article which he likes best, without regard to where he gets it, than if he was prevented by retaliatory prohibitions, or discriminating duties, from so doing. Hence, free trade, which is the means of supplying both the individual, and the aggregate wants of a nation at the cheapest price, should be permitted to the fullest extent, without regard to the restrictions of foreign countries, which we cannot, and should never attempt to control.

To the preceding rule there is one exception, and it is of a temporary nature. When a country is supplied from abroad with a particular species of goods, (for example with cotton goods,) which it

possesses every local advantage for manufacturing within itself, that the country from whence it is supplied enjoys; it is good policy to encourage the establishment of such manufacture at home. Owing, however, to the want of knowledge, and facilities for manufacturing, the cost of producing an article is greater at first, (its quality being taken into account,) than ever afterwards; and this, in most cases, prevents the establishment of such manufactures. Now, the only means whereby this disadvantage can be overcome, is either to prohibit the importation of the same article from abroad, (which is the policy at present adopted by France towards us, in reference to cotton manufactures,) or to protect the home manufacturer by such a high duty on the foreign article, as enables him to compete profitably in the home market, with the foreign manufacturer. By such policy, a permanent saving is gained, for a temporary loss. When the manufacture is fully established, and the requisite skill acquired, all prohibitions and protecting duties may cease; for the country will then, and ever afterwards, supply itself at a cheaper rate than it can be supplied by the foreign country. This result arises from the saving of expense that necessarily attends the freight, carriage, insurance, and agency commissions, unavoidable in the transportation of goods from one country to another.

In countries merely or chiefly agricultural, and which labour under no local disadvantages for manufacturing, the policy above recommended is exceedingly advantageous, and wonderfully calculated to raise the average condition of their inhabitants. By sup-

porting a manufacturing population at home instead of abroad, which, with the cultivators of the soil, become mutual and never-failing customers to each other, even during periods of war and political discord, it raises the value of land. By affording constant employment to a population, which, in the present improved state of husbandry, could only be half employed in cultivating the ground, it operates like improvements in machinery, in increasing the aggregate production of useful articles relative to the population. And hence it augments the aggregate wealth, and raises the average condition of a people.

In a country which labours under local disadvantages, which permanently disqualify it from supplying itself with any particular species of manufactured goods, at so low a price as it can be supplied by a foreign country, the policy under consideration is injudicious. Under such disadvantages, to attempt to establish a manufacture by prohibitions or protecting duties, and to persist in such a system of policy, is merely to throw away money uselessly, to the extent of the difference between the cost of supplying itself with the prohibited article, and being supplied with it from the foreign country without prohibition or protecting duty.

In the United States of America, the duties upon imports, which were originally had recourse to only for financial purposes, have had the effect of prematurely fostering their own manufactures. So long as that country remains only very partially peopled, and the price of labour consequently continues high, it would have been more conducive to their national

prosperity, had the portion of the population, at present engaged in the manufacture of articles which they could import at a cheaper rate from Europe, been employed in clearing the ground, and cultivating food, and articles for exportation, such as cotton, tobacco, &c. Ultimately, however, when the States become so populous that the price of labour sinks as low, or nearly as low as it is in Europe; and other avocations, besides those they have, are required in order to employ the people; the having recourse to protecting duties for the purpose of establishing the cotton and woollen manufactures within their own territories, and which, by raising the raw materials themselves, they possess the greatest advantages for supporting, would be good policy.

When taxes or duties on articles of consumption are necessary for financial purposes, they ought to be shifted, or altered relatively to each other, as little as possible. The consumption of any manufactured article is regulated, not so much by its individual value in use, as by its value in reference to that of other articles which can be used as substitutes. By reducing the duty on any article, for instance on silk, the consumption of silk goods will be increased; but then the consumption of cotton goods will be proportionally diminished. Trades which are upon the increase usually pay more than the average rate of profit; while trades that are upon the decrease, usually pay less. By taking off the duty on silk, the manufacture of silk goods would be increased, and for a time would pay more than the average rate of profit; but the manufacture of cotton goods would be proportionally

diminished, and, for a time, would pay less than the average rate of profit. Nor is the benefit which the country, in such circumstances, derives from the encouragement given to the production of silk goods, a sufficient compensation for the loss sustained by the discouragement given to the production of cotton goods. Suitable manufacturing establishments, persons employed at fixed salaries, and workmen trained to the trade, exist to the extent required to continue the previous supply of cotton goods; whereas establishments require to be enlarged, more persons at fixed salaries employed, and additional workmen trained to the trade, in order to produce an additional supply of silk goods. The buildings and machinery fitted up for the manufacture of cotton goods are partly rendered useless; and the labour of the persons employed at fixed salaries, and the acquired skill of the workmen are partly lost to the community, by the alteration of duties; while nothing in lieu thereof is gained. Hence, it may be laid down as a maxim in commercial policy, that every alteration or shifting of duties from one article to another, for a time diminishes the aggregate wealth, and lowers the average condition of a people.

When capital is paying a less rate of profit in one department of merchandise than in others, it is soon turned from the less into the more profitable channel. And so is it with labourers. When wages are lower in one trade than in another, (the comparative skill required, and other circumstances being taken into account,) the workmen soon change from the one to the other, till an equality of wages is restored. Com-

plaints from interested parties relative to the distress which certain trades experience, in consequence of taxation, when the same system of taxation has been permanent for a length of time, are absurd, and should never be listened to by government. The only rule that should be kept in view in this department of legislation, is, that those duties are the best which are collected with least trouble and expense relative to the amount of revenue ; and which are least liable to give rise to smuggling, and fraudulent evasion of payment. Trade soon accommodates itself to any permanent system of taxation, but never to one that is constantly fluctuating. And the worst Ministry for a mercantile country, such as Great Britain, is one that is continually shifting, and altering the relative proportions of duties upon articles of commerce, in order to please deputations of interested applicants.

A good harvest operates like a sudden diminution of population, in raising the average condition of a people. By lowering the price of provisions, a smaller proportion of the income of individuals is absorbed in purchasing them ; and of course a larger proportion is left to buy clothing, and other manufactured commodities. Hence a good harvest not only lowers the price of food, but by increasing the consumption of manufactures, augments the demand for labour, raises the wages of the labourer, and for a time ameliorates the general condition of society. On the other hand, a bad harvest operates like an increase of population, without a corresponding augmentation of the means of subsistence, in deteriorating the condition of a people. By raising the price of provisions,

an unusually large proportion of the income of individuals is absorbed in purchasing them; and of course, a proportionally smaller amount is left to buy clothing, and all other necessaries, and luxuries. Hence a bad harvest not only raises the price of food, but by diminishing the consumption of manufactures, lessens the demand for labour, lowers the wages of the labourer, and for a time deteriorates the general condition of the community.

In reference to population, a good and a bad harvest produce opposite results. The former by producing a temporary effect in ameliorating the condition of society, encourages marriages, and an increase of population; whereas, the latter, by deteriorating the condition of society, prevents and delays marriages, and tends to diminish population. Good and bad harvests, in these respects, balance each other. They are circumstances which produce no permanent influence in either deteriorating, or improving the condition of society. But an improvement in husbandry, such as better draining, which permanently increases the productiveness of the soil, relative to the number of hands employed in cultivating it, operates like improvements in machinery, in bettering the condition of the community. By leaving an amount of spare labourers, whose industry, in order to support themselves, is soon directed to productive avocations, the quantity of useful articles produced, relative to the population, is augmented. And hence the aggregate wealth of the nation is permanently increased, and the average condition of the people ameliorated.

It is generally believed that the average condition

of the people in this country, would be permanently and greatly ameliorated by free-trade in corn. There can be little doubt, however, that the extent of the anticipated amelioration has been much over-estimated. That a temporary improvement might therefrom result, after trade had recovered from the shock produced by the alteration in the value of commodities, is not improbable; but it is presumable, that little or no permanent amelioration of condition would be thereby effected. Supposing that upon the repeal of the corn laws, a reduction in the average price of all sorts of grain took place to the extent that is anticipated, viz. from 8 to 15 shillings a quarter, without any immediate reduction in the wages of the operatives taking place, it is obvious, according to Malthusian principles, that this amelioration in their condition, would increase the number of marriages. This in a few years would augment the number of consumers of provisions, and ultimately the number of labourers, so much, that their wages would be able to command as little food, as they were before the repeal of the corn laws.

Those who argue for the repeal of the corn laws on the principle, that the reduction of the wages of labour which would thereupon ensue, would enable us to extend our foreign trade, forget that the mass of foreign nations are interested in establishing manufactures in their own countries; and that a slight increase to their protecting duties, would extinguish all prospect of a repeal of the corn laws, having any influence in increasing our foreign trade with such nations. The system of protecting duties established

on the continent of Europe, has already had the effect of enabling them to supply themselves with various kinds of manufactured commodities, at a cheaper rate, than they could now be sent from this country, from which they were formerly supplied. And there is reason to believe, that if peace continues, and especially if the British system of banking, by which capital and credit are rendered available for mercantile purposes, and which is so much wanted on the continent, was generally introduced there, it is probable, that a large proportion of the goods which we at present send thither, would ere long be superseded by the supply afforded by their own manufacturing establishments. And this result may be expected to take place, whether the corn laws be repealed or not.

The wealth of a nation consists in the aggregate produce of its own land and labour; and the greater its amount relative to the population, the higher is the average condition of the people. If the whole population are as constantly employed at present, as they would be after the repeal of the corn laws, any increase of wealth that could therefrom result, would be owing to a small extent of the most inferior soils ceasing to be cultivated. The industry of a portion of the labourers now engaged in cultivating such soils, by being directed to other avocations, might be able to purchase as much food from abroad, as would be sufficient to support the whole of them. Of course the residue of the labourers, in order to obtain a livelihood, would have to direct their industry to the production of other useful articles; and the aggregate amount of these would be the sum total of the in-

creased wealth, which the nation could gain by the repeal of the corn laws.

Foreign trade is merely an exchange of a portion of the commodities which different countries severally produce. It accommodates the taste of mankind for variety, by affording an additional choice of commodities for sale. And according as home or foreign articles, at their respective prices, are more or less preferred, so are they said to be more or less wanted, or in demand. In the long run, the aggregate exports and imports are equivalents in the countries from which they are exported; and merely become enhanced in value by changing their respective places. The merchant is the party that effects the transfer, and gains the profit, which, after deducting the expense, arises out of the enhancement of value consequent to the transfer. Foreign trade is thus limited by the wants of the respective nations which carry it on; and these wants are regulated by the relative value which the respective nations put upon the articles which they have to exchange. The price or exchangeable value of every article sinks as the supply increases, provided the demand be not proportionally increased. Consequently there is a limit beyond which, if the exchange of commodities goes on, in place of being profitable to the merchant who effects the transfer, it is attended with loss. In this case, trade is said to be overdone, and tends to decrease. On the contrary, when the transfer of goods, or of any particular species thereof, from one country to another, pays the merchant who effects it more than

the ordinary rate of profit, it is said to be underdone, and tends to increase.

Thus we see foreign trade is limited, and naturally tends to adjust itself, to the extent that is best calculated for supplying the wants of the respective nations that carry it on. While some articles are paying more than the ordinary rate of profit, others are paying less ; and the merchant who merely looks to his own interest, regulates the supply of the various transferable articles as nearly as possible to the extent that is most desirable, and most advantageous for both nations.

Now, when it is considered that the wealth of a nation consists in the possession of articles useful to mankind, and that it increases according as the amount of useful articles relative to the population becomes greater ; it is obvious, that the value of foreign trade increases according as the amount of imports becomes greater, relative to the amount of exports. And hence the reason, that trading with a country, where, in consequence of manufacturing skill, articles of consumption are cheap, is more beneficial than trading with one where they are dear. If the wages of labour were lowered by a repeal of the corn laws, the price of all our manufactures thereby produced, would be proportionally lowered by the competition of our own merchants and manufacturers, not only in the home, but also in the foreign market. The result would be, that so far as our export trade was concerned, foreign countries would gain all the advantage of the reduction of wages produced by the repeal of the corn laws. For instance, in exchange for a similar amount of cotton, or of wheat from America, we would have to

send a larger amount of cutlery and hardware, (and so of every other exchangeable commodity,) after the repeal of the corn laws, than we do at present.

The anticipated benefit which we would derive from the repeal of the corn laws, depends upon the produce of a smaller number of our labourers engaged in manufacturing avocations, being able to purchase and bring home a greater amount of corn from abroad, than the same number of labourers, directed to the cultivation of inferior soils at home, could produce. M'Culloch, in his notes and supplemental dissertations to his edition of Dr Adam Smith's Wealth of Nations, states, that, in the event of the ports being thrown open, if the price declined eight shillings a-quarter, the loss which the nation, or the consumers of grain in Britain annually sustain by the present corn laws, is no less than £19,200,000. If the price declined ten shillings a-quarter, then the annual loss to Britain by the corn laws is £24,000,000. And, if the price declined fifteen shillings a-quarter, he says, that "the annual loss occasioned by the corn laws to the consumers, cannot amount to less than the enormous sum of thirty-six-millions." By the tables appended to his dissertation on the corn laws, it appears, that the amount of all the kinds of grain, meal, and flour imported into Britain for 15 years previous to 1826, exclusive of what was received from Ireland, and, after deducting what was again exported, does not average half a million of quarters annually. The greatest quantity imported in one year was in 1819, which, after the exclusion and deduction above stated, amounted only to 3,431,584 quarters.

Supposing the corn laws were repealed, all the saving resulting to the country therefrom, would be in the reduced value of the amount of grain which we afterwards annually imported. This is evident from considering, that what we subsequently raised at home, would continue to be raised with the same amount of labour, and would require the same number of labourers as before. Now, estimating the average value of all kinds of grain imported to be two pounds sterling a-quarter, there is reason to think, that though we were to get all the grain for nothing, that we ever will import in any one year after the repeal of the corn laws, it would neither be worth £36,000,000, nor £24,000,000, nor even £19,200,000, which are the respective sums that M'Culloch says would be saved by the repeal of the corn laws, according as a decline in prices equal to fifteen, ten, or only eight shillings a-quarter, was thereby occasioned. M'Culloch states, that the quantity of the different sorts of grain annually consumed in the United Kingdom, has been estimated to be at least 48,000,000 of quarters. Now, his opinions, to be correct, relative to the amount of saving under consideration, would require, that, after the repeal of the corn laws, the whole 48,000,000 of quarters consumed in Great Britain and Ireland, should be imported from abroad at the reduction in price which he mentions, instead of being almost wholly raised at home. But there is nothing more certain, than that, though the corn laws were repealed, nearly as great an amount of grain would continue to be raised at home as at present; and therefore no very great additional quantity would

be imported from abroad. The only difference would be, that in consequence of being able to receive supplies from abroad, lower than the present home price, the price of home-raised grain would sink to a similar level. But this difference of price, which, according to M'Culloch's estimate, would be gained to the country, would be lost to the landlords; for they would have to let their farms at a corresponding reduction of rent. M'Culloch's notion that not above a fourth part of what he considers the saving that would accrue to the consumers of grain, would be lost to the landlord in the shape of rent, is obviously fallacious from considering, that almost the whole of the lands at present in cultivation would continue to be cultivated, after the repeal of the corn laws, at a reduction of rent exactly proportional to the reduced value of grain. And it is also an error to suppose, that the reduction in the price of all necessaries and luxuries, would be reduced by the repeal of the corn laws, in the same proportion as the landlord's rents.

Again, while M'Culloch supposes that the repeal of the corn laws would reduce wages, and the price of manufactured commodities, as much as the price of corn, he overlooks the fact, that we would in this case, have to export a correspondingly larger proportion of manufactured articles in return for the grain, cotton, sugar, wines, timber, and other foreign articles that we imported. The same principles that regulate foreign trade at present, would continue to do so after the repeal of the corn laws. If British manufactures were reduced in price in the home market by the repeal of the corn laws, they would be corres-

pondingly reduced in the foreign market. For otherwise, capital would soon get turned from supplying the home market, into the more profitable trade of supplying the foreign market; and so would continue, till an equality in the profits of capital invested in the home and foreign trade, was re-established. Hence another reason, why the repeal of the corn laws would not be attended with the benefit to this country which M'Culloch supposes.

The policy hitherto adopted by governments in the mutual arrangement of tariffs, has always been to get the duties on imports reduced as low as possible; while little or no attention is paid to the duty upon exports. But if any policy is required in the matter, the reverse ought to be the case. As taxes upon articles of consumption are always in the end paid by the consumer, it is obvious, that taxes upon imports are paid by ourselves; whereas taxes upon exports, are paid by the consumers of them in foreign countries. Now if there is any article which we export to a foreign country, which they must have, and which they cannot get from any other quarter, it is obvious, that by taxing this article before it is exported, we make the foreign country pay a portion of our taxation. On the same principle, by prohibiting foreign vessels, and foreign manufactures from entering the ports of our colonies, we might make our colonies pay a portion of our taxation, by taxing our exports thither. But we would thereby injure the condition of the colonies in a greater degree, than we benefited ourselves.

In like manner, if upon the repeal of the corn laws,

we were to tax all our exports, so as to raise them in the foreign market to the same price as at present, foreign nations would be made to pay taxes upon what we exported them, equivalent to the difference in the price of such articles in the home market, before and after the repeal of the corn laws. Such a line of policy however, would in all probability be soon met by retaliatory counteractives, which might teach us the propriety of resorting to the system of reciprocity. For instance, the United States of America, by way of retaliation, might tax all the tobacco, flour, &c., which they export to this country. And if they were to tax all the cotton which they export to Britain, while they allowed it to be shipped to all the other countries of Europe free of taxation, they would seriously injure our cotton manufactures, and would probably destroy, at least for a time, all our foreign trade in cotton goods. It might be thought that we are protected against the adoption of such a measure on the part of the United States, by the circumstance, that it would injure themselves as much, if not more, than it injured us. For in the first place, they would not be able to dispose of the whole of their surplus cotton ; and in the second place, by encouraging the growth of cotton in other quarters of the globe, it would tend to render us independent of them in future. It is perhaps however just as well for both parties, that neither of them provokes the other to retaliate, by commencing such a selfish line of policy.

I am disposed to think, that if the corn laws were repealed, the price of corn in foreign markets would so advance, that the reduction which would take place

in Great Britain, would be much less than is generally supposed. If, however, the reduction was as great as has been generally estimated, an immediate repeal of the corn laws would be attended with very serious evils in a national point of view, and very great injustice to individuals. Thus all leases of farms would have to be annulled, or otherwise the farming interest would be ruined. Again, the value of land would sink so much in price, that landlords who had borrowed money upon their estates, to half or two-thirds of their value, would be thereby deprived of their right to the other proportion; and a similar remark is applicable to those who have borrowed money upon household property or machinery. Again, as the wages of labour would ultimately fall proportionally to that of food, the value of the annual aggregate produce of land and labour estimated in pounds sterling, after the repeal of the corn laws, would be considerably reduced; and consequently, the interest of the national debt, and all fixed salaries, which in pounds sterling remained as before, would absorb a larger proportion of the aggregate produce of land and labour than they do at present, and accordingly would be felt as a proportionally heavier burden.*

* The obvious fact stated in the sentence immediately preceding the asterisk M'Culloch denies. He conceives that the £19,200,000 annually, (supposing that to be the aggregate reduction in the price of the whole grain consumed in Britain, after the repeal of the corn laws,) would be a saving to the consumers of it, which would enable them to pay that additional amount of taxes, without their condition being more reduced than they are at present by the existence of the corn laws. His error here lies in forgetting, what he admits in other passages, that the wages and income of

It may be said that these evils might be obviated, by simultaneously reducing the size of the sovereign, and of the other coinage, proportionally to the reduction in the value of grain, and the wages of labour. But then it is impossible to anticipate correctly the extent of reduction in the price of grain and the wages of labour, that would either immediately or ultimately follow the repeal of the corn laws. And even though this could be done, still that is not all the information required. Though the price of articles of home manufacture, so far as workmen's wages constituted a part thereof, might fall in proportion to the reduction of wages, it does not follow that the interest of capital, and the profit of the manufacturer, which also constitute a part of the price of every manufactured article, should also fall in an equal proportion. Besides, the price of all articles raised abroad, such as cotton, silk, sugar, wines, tea, coffee, &c., would not be in the slightest degree affected, by the reduction in the workmen's wages, expected to result from the repeal of the corn laws. Hence it is obvious, that any reduction in the weight of the sovereign proportional to the reduction in the value of grain, even supposing that could be correctly anticipated, (which is impossible,) would be a gross act of injustice towards all who had money lent. And consequently, the anticipation of such a measure being adopted, would produce great commercial calamity, by occasioning a run upon the banks for gold and silver of the present weight, in order to hoard it; and also by the annihilation of

the consumers of grain, would ultimately be reduced in proportion to the reduction in the price of grain.

credit, and the calling up of all lent money, to which it would give rise. In short, a government that would for a moment entertain the idea of tampering with the currency under any circumstances whatever, would show their utter incompetence to legislate for a commercial country.

Lastly, owing to the measures adopted by foreign governments in order to foster, and establish manufactures in their own countries, by means of protecting duties; and which, as we formerly explained, is wise policy where the countries labour under no local disadvantages for manufacturing, it is probable, that the price of grain in foreign countries will gradually assimilate to what it is in Great Britain. In the abstract, I am favourable to free trade in grain, as well as in every other commodity, on the principle, that, like a slight improvement in the machinery for husbandry, without any diminution in the supply of grain, it might disengage a few, and only a few workmen, whose industry might be directed to the production of some other useful article. Nevertheless, when the evils above enumerated, which in our artificial state of credit and taxation, would attend the immediate repeal of the corn laws, are considered in conjunction with the prospect of a gradual assimilation in the price of grain at home and abroad, I am disposed to think, that if any repeal of the corn laws is to take place, it ought to be a prospective and gradual measure, such as a reduction of one-third of the duty, (supposing it first to be converted into a fixed amount,) to come into operation ten years hence; another third, twenty years hence; and a total repeal not to take place sooner

than thirty years from the present period. Of course it would have to be also enacted, that farmers who had leases with more than ten years to run, were entitled to have them shortened to that period, if they gave sufficiently early notice to their landlords. By the adoption of a gradual measure of this kind, public clamour would be somewhat put down; and the repeal of the corn laws would probably be effected without doing injustice to any party; and actually without producing any material change in the price of grain.

We have thus, at considerable length, inquired into the influence of various measures and kinds of policy, in determining the aggregate wealth, and the average condition of a people. The conclusion to which we come, is, that the condition of mankind in any country, can be permanently ameliorated only by means calculated to increase the amount of food, or of the other necessaries and comforts of life, relative to the population. In order to further these desirable objects, measures and policy which contribute to render the preventive checks more efficacious in restraining population, as well as those which increase the annual produce of land and labour relative to the population, should be adopted; while measures and policy calculated to produce contrary effects, should be avoided. What these measures and kinds of policy are, has been sufficiently pointed out, and explained in the preceding pages. Upon this subject we will only farther remark, that as ignorance and crime are invariably found to increase with the poverty of the lower orders of society, the means which are most

calculated for ameliorating the average condition of a people, are also best adapted for raising their intellectual and moral character.

It is almost unnecessary to apply any of the preceding observations, except for the sake of form, to Mr Owen's system. In a state of society such as he proposes, where all property was held in common, and where every one had a right to draw upon the public stores according to his wants, the preventive checks to population which raise the average condition of mankind by limiting their numbers, could have no influence. Under this, as well as under all other systems of equality, where individual exertion and prudence, and the sacrifice of immediate inclination, hold out no prospect of individual benefit, there could be no stimulant to industry; no personal providence nor economy; no thinking before marriage how they were to provide for a wife and family; no hope of bettering their condition by remaining single; and no fear of making it worse by entering into the state of marriage. Hence the number of inhabitants in each parallelogram would rapidly increase, and soon exceed the limits assigned it. What is to be done with the surplus population? Perhaps it may be said, form new parallelograms. But when the whole land is occupied, what then is to be done? Nothing farther can be done. The land itself cannot be increased, and its productiveness cannot be indefinitely increased. In the vegetable world, plants, by means of the reproductive principles with which they are endowed, increase and multiply till the soil is capable of supporting no more. In like manner, the lower animals, if

left to the freedom of their own will, multiply till want or scarcity of food, checks their farther tendency to increase. And so would it be with the human species under any system of equality such as Mr Owen's, which, instead of equalizing wealth, by destroying the influence of the preventive checks to population, would equalize and increase poverty. In such circumstances, instead of a few being reduced to poverty, population would inevitably increase, till the whole community were restricted to the smallest amount of nourishment capable of supporting life, and perpetuating the species. And in years of scarcity, universal starvation and incapacity to assist each other, would reduce the condition of man to the lowest possible state of degradation and misery.

Under the present system of society, which, by every one working for his own individual interest, is productive of such an immense variety of ranks and degrees of wealth, a very limited number, consisting of only the poorest class, are reduced to the lowest subsistence, which in this country at least, is considerably above the starving point. As population increases, the preventive checks gradually act with augmenting efficacy, till in conjunction with the positive checks, all tendency to increase is arrested, and population becomes stationary. Indeed so mild, silent, and unseen, and so equal to all classes of society, are the preventive checks in their operation, that their influence, though seemingly as apparent as the sun at noon-day when pointed out, was never till recently detected.

Though joint-stock societies have been known to

exist, and for a time to prosper in half-peopled countries, such as America, where labour is high paid; yet their regulations have all been much wiser, and infinitely better adapted for insuring success, than those which Mr Owen proposes. Such joint-stock societies have generally, if not always, been composed of persons belonging to the same religious sect, driven by persecution from their native country. By an arrangement of Providence, the members of such persecuted sects, receive some compensation for the injustice dealt them by their fellow-men, by becoming mutually attached, and more amicably disposed towards each other. And it is invariably observed, that ultimately, when the persecution to which they were once subject has long ceased, and passed into oblivion, the bond of union which kept them together is broken, and the association dissolves by the mutual consent of its members.

Supposing it possible that Mr Owen's system could go on till population was checked by starvation, it is evident that at this point selfishness must get the upper hand, and the strong would oppress the weak in order to save themselves from starvation. War originating in the same cause, would take place between the occupiers of the different parallelograms; and all the malignant feelings in human nature being thereby excited, slaughter, rapine, and devastation, would spread around, till some mighty revolution shivered to pieces this visionary fabric, and left man to provide for himself, and to reap the fruits of his own industry, which Providence has ordained to be not merely the most natural system, and that which is

most conducive to human happiness, but the only state in which society can permanently exist.

There are some borrowed maxims to be met with prefixed to Mr Owen's plan, which are calculated beforehand to give it something like a plausible appearance; such as, 1st. That labour, properly directed, is the source of all wealth. 2d. That, when properly directed, a man's labour is of far more value to the community, than the expense necessary to maintain him in considerable comfort. 3d. That the direct effect of every addition to scientific, or mechanical and chemical power, is to increase wealth. These, and some such others, are borrowed truths that every person knows. And though Mr Owen prefixes them to every promulgation of his plan, and a person might thereby be led to conceive that they were its fundamental principles, they are subsequently entirely lost sight of, and form no part of them. Indeed, his system is generally diametrically opposed to such maxims. For instance, that a man should work alternately at each trade; or that the divisions and subdivisions of labour should be abolished; or that spade husbandry should again be introduced, instead of that by the plough and harrow; or that gold and silver as a circulating medium should be done away with, and the old system of barter resorted to in its place; is surely neither directing a man's labour properly, nor taking advantage of the scientific and mechanical knowledge possessed by mankind, for promoting the increase of wealth.

The cleanness of the establishment, and the external appearance of comfort in the dwellings of the

work-people at New Lanark, which, combined with the beauty of the scenery, attracts the visiter's attention, are also quite distinct from Mr Owen's plan. They merely show, (an example worthy of imitation,) the influence of a master over his workers in a sequestered part of a country, when directed towards these objects.

Upon reviewing Mr Owen's system, we are struck with its numerous glaring absurdities and impossibilities; with the inadequacy of the means for accomplishing the proposed ends; and with the palpable ignorance of human nature, and of the doctrines of political economy, which it everywhere displays. Something analogous to it may be adapted upon a limited scale to the state of criminals confined to hard labour, or to the forlorn submissive condition of paupers and slaves under the subjection of an arbitrary master; but it is utterly destitute of every thing calculated to promote the liberty, independence, wealth, and happiness of mankind at large. Even his system of education,* which is considered the

* It is to be lamented that the bigotry of the age still retards and increases the expense of the initiatory department of education, viz. learning to read, by compelling teachers to use as school-books, only religious works, and such as contain select specimens of English composition in prose and verse. Children can neither understand, nor receive improvement from the moral lessons which works of this description inculcate; nor can they form the slightest appreciation of the beauties they contain. In fact, the reading of them is felt by children as a disagreeable act of drudgery.

Reading is simply combining together, upon inspection, letters or characters which have severally a determinate force or sound, so as to form words. And learning to read, is merely learning

only part of his plan not totally irrational, seems more calculated to attract the attention of a superficial observer, than to stand the test of close examination. Its great expense, compared with its utility, precludes all chance of its being generally adopted; and it may be safely predicted, that it never will be found in a single instance, productive of any of those great advantages, which its admirers expect. Similar observations are applicable to the Infant school systems of education, at present so much in repute. They are chiefly remarkable for the introduction of a systematic plan of clapping hands, and other things equally frivolous and unimportant.

Notwithstanding the imperfect nature of Mr Owen's plan, he is so certain of its being adopted, that he says "a longer continuance of the existing arrangements is impossible, that every body cries something must be done, and that his system will be adopted, in spite of all that prejudices in favour of old established customs can do." Disregarding his sanguine expectations, which are quite of a piece with the rest of his notions, let it be, in conclusion, observed, that it may be within the boundary of possibility, but is barely within that of probability, that a man who has

the art of doing this with rapidity,—a thing which can only be acquired by practice. Now, the obvious means of accelerating this department of education, is to use as school-books, only such as children experience pleasure in reading, and which they would have an inclination to read whenever they were at leisure. Robinson Crusoe has been recommended by a man of genius, as a book in every respect fitted for amusing, and instructing the minds of children. This, therefore, or others of a similar nature, should only be used as school-books in teaching children to read.

been inventing nothing all his days, but theories for the amelioration of his species that are absurd and incapable of being reduced to practice, will ever produce one that is rational, and at the same time practicable.

APPENDIX.

The annexed map, on which are delineated Humboldt's isothermal lines, and the table of temperatures of the principal places contained within the isothermal zones, which are severally bounded by them, are taken from the article Meteorology in the Encyclopædia Metropolitana. The map and table of temperatures, are referred to at page 249 of our treatise on the Causes and Principles of Meteorological Phenomena.

On the map, the number inserted at both extremities of each of the isothermal lines, is the mean annual temperature in degrees of Fahrenheit for all places along the isothermal line; and the lines are severally denominated, and distinguished from each other, by that mean temperature. Thus the isothermal line with 32° marked at both its extremities, is denominated the isothermal line of 32 degrees; and so of all the others.

The isothermal lines exhibit a sameness in the mean annual temperature at the tropic of Cancer, whether it be land or water. Thus the isothermal line of 77° has almost no curve whatever, and coincides nearly with the tropic of Cancer, from which, on the map, it can hardly be distinguished; whereas, the other isothermal lines become more curved as they recede farther towards the north. The reasons why it is so, we have endeavoured to explain in our meteorological treatise, beginning at page 251.

According to Playfair a sameness in the mean annual temperature, whether it be land or water, occurs about the 30th parallel of latitude; and nearer the equator than that parallel, the mean annual temperature increases upon receding from the ocean, a fact which we have explained at page 255. In our chapter on Temperature, we have adhered to Playfair's statement in preference to that of Humboldt, principally because fixing upon the parallel that coincides with the tropic of Cancer, as being that at which the mean annual temperature is uniform, whether it be land or water, looks more like modifying facts to support a theory, than the other.

The more northerly isothermal lines also exhibit a lower mean annual temperature for the latitude in America, than on the old continent. Thus the extremity of the isothermal line of 32° in America, is nearly 5 degrees of latitude lower than the other extremity in Asia. The reasons why it is so, we have attempted to explain in our meteorological treatise, beginning at page 256.

TABLE OF TEMPERATURES. *(From the Encyclopædia Metropolitana.—Article Meteorology.)*

Isothermal Zones.	Names of Places.	Position. Latitude North.	Longitude.	Height in Feet.	Mean Temperature of the Year.	Distribution of Heat in the different Seasons. Mean Temp. of Winter.	Mean Temp. of Spring.	Mean Temp. of Summer.	Mean Temp. of Autumn.	Maximum and Minimum. Mean Temp. of Warmest Month.	Mean Temp. of Coldest Month.
Isothermal Zones from 32° to 41°.	Nain	57° 8′	61° 20′ W	0	26·42°	—0·60°	23·90°	48·38°	33·44°	51·80°	—11·28°
	*Enontekies	68 30	20 47 E	1356	26·96	+0·68	24·98	54·86	27·32	59·54	—0·58
	Hospice de St Gothard	46 30	8 23 E	6390	30·38	18·32	26·42	44·96	31·82	46·22	+15·08
	North Cape	71 0	25 50 E	0	32·00	23·72	29·66	43·34	32·08	46·58	22·10
	*Uleo	65 3	25 26 E	0	35·08	11·84	27·14	57·74	35·96	61·52	7·70
	*Umeo	63 50	20 16 E	0	33·26	12.92	33·80	54·86	33·44	62·60	11·48
	*St Petersburg	59 56	30 19 E	0	38·84	17·06	38·12	62·06	38·66	65·66	8·60
	Drontheim	63 24	10 22 E	0	39·92	23·72	35·24	61·24	40·10	64·94	19·58
	Moscow	55 45	37 32 E	970	40·10	10·78	44·06	67·10	38·30	70·52	6·08
	Abo	60 27	22 18 E	0	40·28	20·84	38·30	61·88	40·64	——	——
Isothermal Zones from 41° to 50°.	*Upsal	59 51	17 38 E	0	42·08	24·98	39·38	60·26	42·80	62·42	22·46
	*Stockholm	59 20	18 3 E	0	42·26	25·52	38·30	61·88	43·16	64·04	22·82
	Quebec	46 47	71 10 W	0	41·74	14·18	38·84	68·00	46·04	73·40	13·81
	Christiana	59 55	10 48 E	0	42·80	28·78	39·02	62·60	41·18	56·74	28·41
	*Convent of Peyssenburg	47 47	10 34 E	3066	42·98	28·58	42·08	58·46	42·98	59·36	30·20
	*Copenhagen	55 41	12 35 E	0	45·68	30·74	41·18	62·60	48·38	65·66	27·14
	*Kendal	54 17	2 46 W	0	46·22	30·86	45·14	56·84	46·22	58·10	34·88
	Malouine Islands	51 25	59 59 W	0	46.94	39·56	46·58	53·06	48·46	55·76	37·40
	*Prague	50 5	14 24 E	0	49·46	31·46	47·66	68·90	50·18	——	——
	Gottingen	51 32	9 53 E	456	46·94	30·38	44·24	64·76	48·74	66·38	29·66
	*Zurich	47 22	8 32 E	1350	47·84	29·66	48·20	64·04	48·92	65·66	26·78
	*Edinburgh	55 57	3 10 W	0	47·84	38·66	46·40	58·28	48·56	59·36	38·30
	Warsaw	52 14	21 2 E	0	48·56	28·76	47·48	69·08	49·46	70·34	27·14
	*Coire	46 50	9 30 E	1876	48·92	32·36	50·00	63·32	50·36	64·58	29·48
	Dublin	53 21	6 19 W	0	49·10	39·20	47·30	59·54	50·00	61·16	35·42
	Berne	46 5	7 26 E	1650	49·28	32·00	48·92	66·56	49·82	67·28	30·56
	*Geneva	46 12	6 8 E	1080	49·28	34·70	47·66	64·94	50·00	66·56	34·16
	*Manheim	49 29	8 28 E	432	50·18	38·80	49·64	67 10	49·82	68·72	33·44
	Vienna	48 12	16 22 E	420	50·54	32·72	51·26	69·26	50·54	70·52	26·60

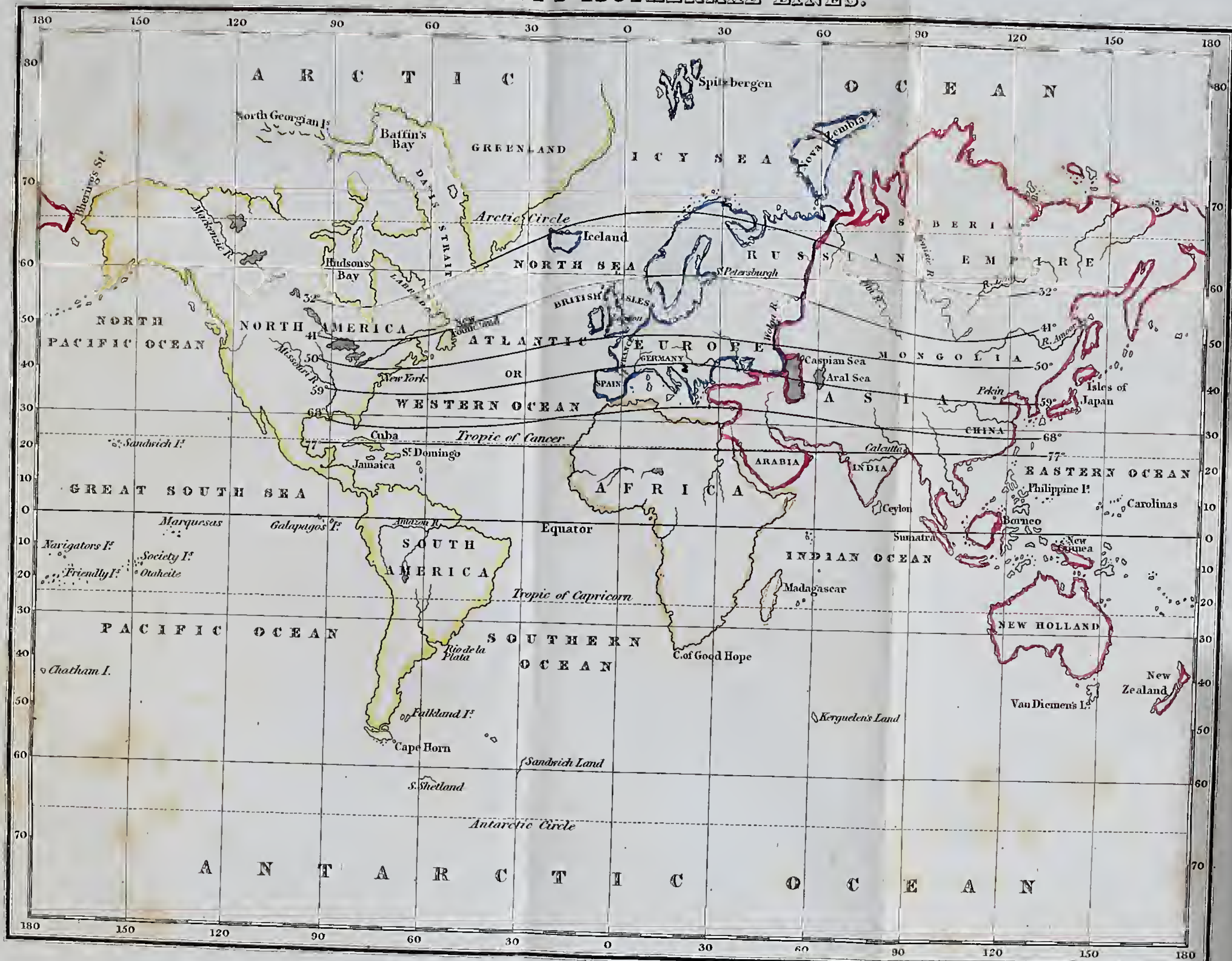
(*) At the Places thus distinguished, the Temperatures given are the result of at least 8000 observations.

TABLE OF TEMPERATURES.—*Continued.*

Isothermal Zones.	Names of Places.	Position. Latitude.	Position. Longitude.	Position. Height in Feet.	Mean Temperature of the Year.	Distribution of Heat in Different Seasons. Mean Temp. of Winter.	Mean Temp. of Spring.	Mean Temp. of Summer.	Mean Temp. of Autumn.	Maximum and Minimum. Mean Temp. of *Warmest* Month.	Mean Temp. of *Coldest* Month.
Isothermal Zones from 50° to 59°.	*Clermont	45° 46′	3° 5′ E	1260	50·00°	34·52°	50·54°	64·40°	51·26°	66·20°	28·04°
	*Buda	47 29	19 1 E	494	51·08	33·98	51 08	70·52	52·34	71·60	27·78
	Cambridge, (U.S.)	42 25	71 3 W	0	50·36	33·98	47·66	70·70	49·82	72·86	29·84
	*Paris	48 50	2 20 E	222	51·08	38·66	49·28	64·58	51·44	65·30	36·14
	*London	51 30	0 5 W	0	50·36	39·56	48·56	63·14	50·18	64·40	37·76
	Dunkirk	51 2	2 22 E	0	50·54	38·48	48·56	64·04	50·90	64·76	37·75
	Amsterdam	52 22	4 50 E	0	51·62	36·86	51·62	65·84	51·62	66·92	35·42
	Brussels	50 50	4 22 E	0	51·80	36·68	53·24	66·20	51·08	67·28	35·60
	*Franeker	52 36	6 22 E	0	51·80	36·68	51·08	67·28	54·32	69·08	32·90
	Philadelphia	39 56	75 16 W	0	53·42	32·18	51·44	73·94	56·48	77·00	32·72
	New York	40 40	73 58 W	0	53·78	29·84	51·26	79·16	54·50	80·78	25·34
	Cincinnati	39 6	82 40 W	510	53·78	32·90	54·14	72·86	54·86	74·30	30·20
	*St Malo	48 39	2 1 W	0	54·14	42·26	52·16	66 02	55·76	66·92	41·74
	Nantes	47 13	1 32 W	0	54·68	40·46	54·50	68·54	55·58	70·52	39·02
	Pekin	39 54	116 27 E	0	54·86	26·42	56·30	82·58	54·32	84·38	24·62
	*Milan	45 28	9 11 E	390	55 76	36·32	56·12	73·04	56·84	74·66	36·14
	Bordeaux	44 50	0 34 W	0	56·48	42·08	56·48	70·88	56·30	73·04	41·00
Isothermal Zones from 59° to 68°.	Marseilles	43 17	5 22 E	0	59·00	45·50	57·56	72·50	60·08	74·66	44·42
	Montpellier	43 36	3 52 E	0	59·36	44·06	56·66	75·74	60·98	78·08	42·08
	*Rome	41 53	12 27 E	0	60·44	45·86	57·74	75·20	62·78	77·00	42·26
	Toulon	43 7	5 50 E	0	62·06	48·38	60·80	75·02	64·40	77·00	46·40
	Nangasacki	32 45	129 55 E	0	60·80	39·38	57·56	82·94	64·22	86·90	37·40
	*Natchez	31 28	90 30 W	180	64·76	48·56	65·48	79·16	66·02	79·70	46·94
Isothermal Zones from 68° to 77°.	*Funchal	32 37	16 56 W	0	68·54	64·40	65·84	72·50	72·32	75·56	64·04
	Algiers	36 48	3 1 E	0	69·98	61·52	65·66	80·24	72·50	82·76	60·08
Isothermal Zos above 77°.	*Cairo	30 2	31 18 E	0	72·32	58·46	73·58	85·10	71·42	85·82	56·12
	*Vera Cruz	19 11	96 1 W	0	77·72	71·96	77·90	81·50	78·62	81·86	71·06
	*Havannah	23 10	82 13 W	0	78·08	71·24	78·98	83·30	78·98	83·84	69·98
	*Cumana	10 27	65 15 W	0	81·86	80·24	83·66	82·04	80·24	84·38	79·16

(*) At the Places thus distinguished, the Temperatures given are the result of at least 8000 observations.

HUMBOLDT'S ISOTHERMAL LINES.



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